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An analysis of Indian rainfalls using the median as a statistic.

BY

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AN ANALYSIS OF INDIAN RAINFALLS USING THE MEDIAN AS A STATISTIC.

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Summary.—A general test, called the H test, which was recently suggested by Dr S. R. Savur (*Proc Ind Acad Sci June 1937*) has been used in this paper to analyse the monthly rainfall data at thirtyfive representative stations in India. The analysis, which is based on the 5% limits for random chance for H, reveals the following points —

(*i*) The rainfall associated with thunderstorms in the hot weather months is sharply differentiated from the rainfall of the monsoon months

(*ii*) During the monsoon months a significant increase in rainfall amount is found from June to July, except in Burma and parts of northeast India. July, which has generally the highest rainfall, is found to show no significant difference from August, except in the western parts of the Peninsula. September shows generally a distinct decrease from August, except in the southern and eastern parts of the Peninsula

It is usual to adopt the arithmetic mean extensively in statistical analysis. Such use is justified in the case of samples from normally distributed populations. When, however, the original distribution is skew, an analysis of the data using the mean loses much of its value. A graphical method of analysing rainfall data by using the median and the inter-quartile range to typify a sample has therefore been recently put forward by P. R. Crowe in (1) and later on in (2). The method has been followed by H. A. Matthews (3) in discussing rainfall types in India. In these papers we do not find any satisfactory theoretical justification of the method employed. Very recently S. R. Savur (4,5) has suggested a method of statistical analysis using the median as a statistic. He has shown that the analysis is quite general in that it is applicable to all cases irrespective of the frequency distributions. In this paper an analysis is made of monthly rainfall records of selected stations in India by using the median in the manner suggested by Savur.* The method is particularly appropriate in the case of rainfall in arid or semi-arid places as it is well-known that the frequency distribution of rainfall in those areas is very skew.

*After the preparation of this analysis, the attention of the author was drawn to a paper by W. R. Thomson in *Ann. Math. Stat.*, Vol VII, 1936, where a method of using the median in tests of significance similar to that of S. R. Savur has been developed. The formulæ developed therein are somewhat complex and not so easy of manipulation as those given by Savur.

Suppose we wish to know whether one month at any place is rainier on the average than another ; then the usual procedure has been the following :—

If we have records for n years we have n values of total monthly rainfall for each of the two months. Using " Student's " t test, say, we find out if the means of these two samples are significantly different from each other. If they are not, we conclude that one month cannot be said to be wetter than the other , while if a significant difference be found, that month, having a bigger mean, is taken to be rainier than the other In a similar manner it is tested which of two places is rainier on the average For reasons mentioned above it appears better to use the म test ([5]) instead for this purpose. The method of procedure is as follows —

Let us take the case of two months The rainfall records of each of the two months for all available years are first arranged in, say, the ascending order of magnitude. Let these be denoted by $y_1\ y_2\ y_3 \qquad y_n$ The median for each month can be found out. Suppose we use the 5% limit for random chance. Then we use relation (*iv*) on p. 570 in reference (5) and calculate the 5% interval for the median rainfall of that month as explained in reference (5) If the two 5% intervals have a common part, we cannot say that one month is rainier than the other But if the intervals have no common part, then that month with the bigger median can be said to be wetter than the other

The 5% intervals for म in the case of rainfall in each of the twelve successive months for thirtyfive representative stations in India have been worked out in the manner outlined above and the results set out in *Table I* In this table the median rainfall in each month is shown in italics A scatter diagram (after the manner of P. R. Crowe) has been drawn for one station, namely, Poona, by plotting the monthly totals year by year and is given in *Plate I* The height of the shaded area in the diagram represents the 5% interval for the म of rainfall of each month. The position of the median is indicated by a horizontal arrow within the shaded area. It can be seen that the rainfall amounts included in the shaded areas (or the 5% interval) define a group. As mentioned above, the rainfall of any month is significantly different from that of any other month if the 5% intervals corresponding to these two months have no common part

It often happens that the 5% intervals for म in a few successive months, though showing no significant difference (as defined above) from any one month to the next succeeding month, assume certain typical forms Hence, if we are analysing the incidence of rainfall in consecutive months at any palce according to the म test it becomes necessary to define each of the typical types of distributions of the 5% intervals for म we are likely to meet with

(*a*) Suppose the positions of the 5% intervals for the म of rainfall in two successive months A and B are those shown in *Fig. 1.* In this case the 5% interval for the म of rainfall in the month B is completely above that for A and hence has no common part with it The amount of rainfall in the month B is therefore significantly greater than that in the month A.

A B

FIG. 1

(*b*) If the positions of the 5% intervals for μ in three successive months, A, B, and C are as in *Fig* 2, where there is a significant discontinuity between the alternate months A and C though those of adjacent months AB and BC overlap, we will define the change in the amount of rainfall from month A to month C to be gradual or progressive

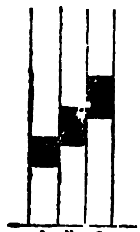

FIG. 2

(*c*) Let the positions of the 5% intervals for μ in four successive months A, B, C, and D be represented by rectangles as in *Fig* 3 We notice that the positions of the 5% intervals in the months A, B, and C arrange themselves as in (*b*) while there is a significant decrease from C to D In this case we will say that there is a gradual increase in the amount of rainfall from month A to month C and a sudden decrease from month C to month D

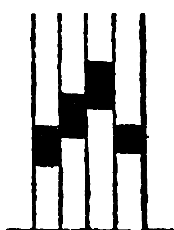

FIG. 3

(*d*) When the positions of the 5% intervals for the μ of rainfall in four successive months A, B, C and D are as shown in *Fig* 4*a*, such that there is an area $XX'Y'Y$ common to all these months in their respective 5% intervals, the median rainfall of each of these months may fall within this common area. We will say that in this case the rainfall is evenly distributed in these months

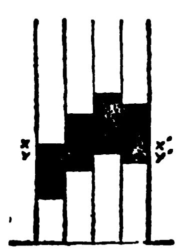

FIG 4 a.

It is however necessary to impose some limitation to this definition of " even distribution ". If the upper and lower limits for the μ of rainfall in a number of consecutive months are persistently higher (or persistently lower) from month to month, consistent with the condition for even distribution mentioned above (*viz.*,

that there is an area common to all these months in their respective 5% intervals) we should perhaps consider whether in this case there is a progressive increase (or progressive decrease) in spite of the 5% intervals having a common part. Let us take a hypothetical case where the positions of the 5% intervals in a few successive months are as shown in *Fig 4b*. Can this be possible by random chance when all the months have a common μ? We can tackle this problem in the following way:

FIG 4b

Let the chance of the upper limit for μ in the month B being greater than that in the month A be p_1

Similarly let the chance of the upper limit of the 5% interval in the month C being greater than that in the month B be p_2 and so on

$$\text{Obviously } \tfrac{1}{2} > p_1 > p_2 > p_3 \text{ etc}$$

Then, if we are to treat the distribution as "even", the maximum number of consecutive months showing this feature should not exceed the value of n given by the relation $(\frac{1}{2})^{n-1} = 0{\cdot}05$, *i e*, n should not be greater than 5. That is to say, it is only when, say, the upper 5% limit goes on rising (or falling) for six consecutive months or more that we have to say (on the 5% limit for random chance) that, in spite of having a common part for the 5% interval, there is an indication of a progressive increase of rainfall from month to month.

(*e*) Let the positions of the 5% intervals for the μ of rainfall in five successive months A, B, C, D and E be represented as in *Fig 5*. In this case we notice a progressive increase from A to C and a progressive decrease from C to E when each of these groups of three months is considered separately. However the 5% intervals in the months B, C and D have a common area $XX'Y'Y$ and hence according to (*d*) the rainfall is evenly distributed in these months. We therefore define this type as showing a gradual increase from A to B, an even distribution in B, C and D and a gradual decrease from D to E

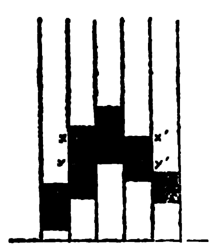

FIG 5

We will use this method of analysis in a few cases

Let us take Poona first. It is seen from *Plate I* that the upper and lower limits of the 5% intervals for the winter months December to March are zero, signifying

practically dry weather during these months. The effect of premonsoon thunder showers which begin in April is seen in the raising of both the limits of प above zero in this month. The increase in thundershowers with the advance of the season is indicated by the 5% range for May (0·21—1·43) being greater than that for April (0·04—0·32). But as these ranges overlap, it cannot be said, according to the criterion set out above, that the rainfall of May is significantly greater than that of April. When next we survey the graph for June प, we see that the 5% interval is 3·31—5·08. These figures are much higher than those for May and there is no overlapping. The rainfall in June which is mostly caused by the monsoon is hence significantly greater than the May rainfall associated with thunderstorms. It is further seen from the plate that the 5% interval for प for July does not have a common part with that for either June or August The rainfall is highest in this month. This bears out the view that July is the month in which the monsoon is most active in the greater part of the Bombay Deccan, except in its southeastern part as represented by Sholapur and Bijapur. There is a distinct decrease in rainfall in passing from July to August, but this decrease is not maintained as September is not significantly different from August. The retreat of the monsoon in October becomes apparent by the significant decrease in rainfall in this month. There is a further sharp decrease in rainfall in passing from October to November indicating that the occurrence of heavy rainfall is rather rare in this month A perusal of the daily weather charts for November in the few years in which Poona had heavy rainfall indicates that rainfall in Novembr in the Bombay Deccan has been usually associated with the incursion of humid winds into this region under the influence of storms or low pressure areas which develop in the Arabian Sea and, moving northwards, ultimately cross the north Konkan and Kathiawar coasts. Occasionally heavy rainfall is also experienced when there is a temporary extension of the northeast monsoon into the Bombay Deccan or when cyclonic storms from the Bay cross the Peninsula in a westnorthwesterly direction. The average rainfall in November is, however, very small, as the number of occasions in which the effect of such cyclonic storms is felt in the Bombay Deccan is very small.

In order to facilitate a comparative study of the regional discontinuities in rainfall probability between adjacent months, graphs (in the form of histograms) showing the 5% interval for प for each month for each of the stations selected have been prepared and are set out in the chart in *Plate II* From this chart, rainfall discontinuities between adjacent months, *i.e* when a significant difference has been obtained on the प test, were read off for each of the stations, the results are summarised in the diagram in *Plate III* In this diagram an arrow appearing between one month and the next indicates a discontinuity in rainfall between the two months on the 5% limit of significance. The arrow is shown upwards if the discontinuity is due to a significant increase in the rainfall in the next month and downwards if the discontinuity is due to a significant decrease in the rainfall.

Let us now take the case of Port Blair. From *Plate II* and also the series of arrows against this station in *Plate III*, it will be seen that there is a sudden increase in rainfall in April. This is to be attributed to premonsoon thunderstorms (6) which begin in this month. On the other hand, it is more appropriate to associate the big increase in May with the Bay monsoon which sets in in the Andamans about the third week in May.* The 5% intervals for प from May to September have a common part (16·48—16·55). From this we may infer that the monsoon rainfall is "evenly distributed" in these months A sudden decrease in rainfall from September to October and the progressive downward trend in the months October, November

* The monsoon rainfall is also associated with thunderstorms in the months May and June.

and December are associated with the retreat of the monsoon from this region in late October and the gradual weakening of the northeast monsoon from October to December. There is again a sudden and significant decrease from December to January showing the withdrawal of the northeast monsoon, and the small and more or less equal amounts of precipitation received in the winter months January to March are merely of local origin due to the insular nature of the country.

It does not appear necessary to give a detailed analysis in the case of all the stations in this manner as the charts in *Plates II* and *III* are fairly self-explanatory. However, a general summary of important regional features brought out by this chart and table is given in the following paragraphs

In almost all the stations selected, the southwest monsoon period, (the period in which practically the whole of the annual precipitation is received in the major portion of India) is not without discontinuities The exception, as we have already seen, is Port Blair with an unbroken series from May to September Kodaikanal shows uniformity of rainfall in the months June, July and August and again in the months September, October and November with a progressive rise in between in September This station is subject to the influence of both the southwest and the northeast monsoon currents and the analysis indicates that the precipitation in the Palni hills due to the northeast monsoon current when it takes control is of greater intensity than that received under the influence of the southwest monsoon current in the months June August. It is also seen that the northeast monsoon continues in undiminished vigour to the end of November in the region around Kodaikanal. It may be observed in passing that thunderstorms are greatest in number at Kodaikanal in the months May and October, *i e*, during the months of unsteady winds, *vide* reference (6), and the precipitation in May due to thunderstorms is significantly greater than that received in June under the influence of the monsoon. Among the other stations, some show an even distribution of rainfall in three successive months during the monsoon period while most of them exhibit no significant difference in rainfall amount only in two successive months These have been grouped together in the following table —

Months of "even distribution" of rainfall	Stations showing this feature.
(5 months) May—September ..	Port Blair.
(3 months) June—August	Mergui, Mandalay, Gauhati, Calcutta, Srinagar, Quetta, Kodaikanal
(3 months) July—September . .	Hyderabad (Deccan), Madras, Colombo.
(2 months) June and July	Karwar, Mangalore, Akyab, Cherrapunji. Nuwara Eliya, Trincomalee.
(2 months) July and August	Karachi, Jacobabad, Peshawar, Leh, Lahore, Delhi, Jaipur, Allahabad, Lucknow, Rangoon.
(2 months) August and September . .	Poona, Nagpur, Bangalore, Trivandrum, Trincomalee

In connection with this table it may be observed that the uniformity of rainfall at Quetta in June, July and August appears to be due to the small amount of precipitation received in these months in Baluchistan

The information summarised in the above table along with certain other peculiarities that have been noticed in the charts in *Plates II* and *III* have been represented

diagramatically in *Plate IV*. The following three main features are brought out in this diagram.

(*i*) The majority of the stations in north India show no significant difference in rainfall amount between July and August. Yet it is observed (from *Plate II*) that both the upper and the lower limits for the R of rainfall for July are consistently higher than the corresponding limits for August at a number of stations. This would indicate a significant excess of July rainfall over that in August, provided the rainfall at each station was independent of that at any other. To verify this point the monthly rainfall data for July and August for the 62 years 1875–1936 for the six representative stations Jaipur, Lahore, Delhi, Allahabad, Lucknow and Patna were scrutinised to see how often an increase or a decrease from July to August occurred simultaneously in all the stations. The results are summarised below.

	All six stations	Delhi, Lahore, Allahabad, Lucknow	Delhi, Allahabad, Lucknow	Allahabad, Lucknow, Patna
Number of occasions when an increase or a decrease from July to August occurred simultaneously	11	16	26	24
Expected frequencies on the assumption that the events are independent of one another	2	8	16	16
Probable error of the expected frequencies	1	2	2	2

It is evident from the relatively large values of the observed frequencies as compared with the expected ones that the variations of the rainfall from July to August at these stations are not independent. An excess or a defect in rainfall in July over that in August in a particular year at any one of the stations is likely to be simultaneously accompanied by a similar excess or defect at most of the stations in the area under consideration. From this it would follow that the relative positions of the 5% intervals for July and August would be similar at all the stations. It is perhaps difficult to give a mathematical proof of this statement, but a good verification in this particular case is obtained on an inspection of the 5% intervals for R for July and August in the four major political divisions, the Punjab, the United Provinces, Bihar and Orissa and Bengal.*

Division	5% interval for R (inches) July	August	Relative positions of the 5% intervals
Punjab	4 83—6 38	4 84–6 39	August July
United Provinces	10 13—12 52	9 83–14 00	July contained in August
Bihar and Orissa	12·12—13 66	12 35—13 63	August contained in July
Bengal	15 10—16 67	14 07—16 14	July August

In all these cases the relative positions of the 5% intervals for July and August are what one would expect from random chance. The analysis may thus be taken

* The 5% intervals for R for these political divisions have been calculated from the data of "Fifty Years' Rainfall" for the period 1875–1924, appearing in the *Indian Meteorological Memoirs*, Vol XXV, Pt. II.

to bring out the frequently observed phenomenon that the monsoon rainfall is evenly distributed in July and August over almost the whole of upper India.

(ii) The coastal region to the south of Bombay shows no significant difference in rainfall amount between June and July, while there is a sudden decrease in rainfall in August and a further decrease in September. On the other hand the north Konkan and Gujarat (as represented by Bombay and Ahmadabad) show rainfall discontinuities between each of the monsoon months, the rainfall increasing considerably from June to July and falling suddenly in August and still further in September. The Arabian sea monsoon sets in normally along the Malabar coast early in June while it takes an additional week to reach Bombay and it is not before the middle or the third week of June that it reaches Ahmadabad. Hence June rainfall is significantly less than that of July both at Bombay and at Ahmadabad.

(iii) The coastal region around Vizagapatam, which is influenced both by the southwest and the northeast monsoon currents, shows a progressive increase in rainfall from June to October

Discontinuities also appear during the northeast monsoon period in the rainfall of the stations representing the area subject to its influence [*viz.*, Vizagapatam, Hyderabad (Deccan), Madras, Kodaikanal and Bangalore] In all these cases a decided fall in the 5% interval for η is noticed in December while judging from the histograms for Hyderabad (Deccan), Madras and Kodaikanal in *Plate II*, it may be surmised that the rainfall associated with the northeast monsoon is more or less evenly distributed in October and November, like the southwest monsoon rainfall in July and August The precipitation due to thunderstorm activity in the summer months is obviously unevenly distributed in time over the greater part of the country. On the other hand, the winter rainfall in northwest India due to the passage of western disturbances appears to be fairly equally distributed in these months The actual rainfall amounts associated with such disturbances are small compared with those received in a thunderstorm or in the activity of the seasonal low during the monsoon, and hence cannot have big variations This may perhaps be the cause of the uniformity noticed above

In conclusion, I wish to thank Dr S R Savour, at whose suggestion and under whose guidance this analysis was made.

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TABLE I.

Mon'hly median rainfall (in ins) and 5 per cent interval.

Month	Port Blair	Mergui	Rangoon	Akyab	Mandalay.
January .	0.27–1.04 *0.58*	0.11–0.65 *0.33*	0 *0*	0 *0*	0 *0*
February .	0–0.45 *0.13*	0.15–1.88 *1.56*	0 *0*	0–0.01 *0*	0 *0*
March .. .	0.03–0.31 *0.13*	2.01–3.23 *2.60*	0–0.08 *0*	0–0.15 *0*	0.02–0.11 *0.06*
April	0.87–2.27 *1.45*	3.34–5.89 *4.13*	0.17–1.62 *0.66*	0.59–1.59 *1.05*	0.45–1.15 *0.68*
May	12.47–16.98 *14.55*	14.29–17.19 *15.96*	9.51–13.70 *11.39*	10.48–13.69 *11.37*	4.13–6.23 *5.56*
June .. .	16.48–21.35 *18.74*	28.01–32.59 *30.18*	16.28–19.68 *18.21*	45.18–50.37 *48.09*	3.27–6.27 *4.94*
July .. .	12.50–16.70 *14.79*	30.58–35.12 *31.68*	21.22–24.89 *22.32*	49.02–57.24 *52.65*	1.97–3.84 *2.43*
August	12.87–16.55 *14.55*	27.81–31.29 *29.16*	17.88–21.35 *19.94*	35.98–46.37 *41.58*	3.39–4.51 *4.02*
September ..	16.21–20.14 *18.31*	23.23–27.85 *26.30*	14.16–15.79 *14.71*	20.65–25.44 *23.61*	4.57–6.69 *5.26*
October .	9.73–12.88 *10.79*	10.14–13.64 *12.13*	5.80–9.15 *6.91*	8.69–13.86 *10.29*	3.79–5.23 *4.45*
November .	7.27–10.34 *8.56*	1.95–4.44 *3.11*	1.13–2.98 *1.75*	1.93–4.19 *2.77*	1.00–2.05 *1.53*
December .	2.84–7.38 *5.21*	0–0.66 *0.13*	0–0.04 *0*	0–0.02 *0*	0–0.18 *0.01*

Month	Cherrapunji	Gauhati	Calcutta	Patna	Allahabad.
January	0.21–0.69 *0.31*	0.18–0.48 *0.31*	0.02–0.21 *0.07*	0.13–0.40 *0.24*	0.12–0.52 *0.29*
February .	1.04–1.80 *1.43*	0.36–0.93 *0.70*	0.27–0.74 *0.49*	0.16–0.57 *0.39*	0.08–0.38 *0.21*
March .. .	5.34–8.53 *6.86*	1.46–2.66 *1.93*	0.53–1.17 *0.82*	0.07–0.25 *0.20*	0–0.15 *0.02*
April .. .	22.61–32.36 *27.74*	5.37–6.34 *5.93*	1.44–2.02 *1.81*	0.03–0.15 *0.06*	0–0.01 *0*
May	36.08–49.74 *44.30*	8.27–10.23 *9.10*	3.99–5.05 *4.52*	0.53–1.39 *0.87*	0.02–0.11 *0.06*
June .. .	93.92–110.82 *104.79*	10.95–12.79 *11.82*	9.33–11.75 *10.66*	5.09–7.20 *5.53*	1.70–3.94 *3.07*
July .. .	87.31–111.56 *95.38*	9.87–12.68 *11.50*	11.49–13.08 *12.24*	9.35–12.98 *10.73*	9.89–13.11 *11.13*
August	62.74–82.73 *71.07*	9.33–11.85 *10.11*	11.30–13.43 *12.43*	8.52–11.82 *10.08*	8.61–11.45 *9.44*
September ..	34.91–45.23 *39.81*	5.61–8.09 *6.66*	8.20–9.82 *9.05*	5.21–8.92 *7.18*	4.62–6.85 *6.11*
October .	7.55–15.75 *10.47*	1.60–3.25 *2.51*	3.49–4.98 *4.01*	1.01–2.25 *1.61*	0.09–1.89 *0.84*
November ..	0.14–0.67 *0.37*	0.07–0.42 *0.27*	0–0.14 *0.03*	0 *0*	0 *0*
December ..	0 *0*	0–0.05 *0*	0 *0*	0 *0*	0 *0*

TABLE I.—*contd.*

Monthly median rainfall (in ins.) and 5 per cent interval.

Month.	Lucknow	Delhi	Jaipur.	Lahore	Srinagar.
January	0·20–0·66 *0·11*	0·35–0·89 *0·50*	0·05–0·24 *0·15*	0·35–0·92 *0·49*	2·12–3·16 *2·55*
February	0·10–0·45 *0·20*	0·13–0·68 *0·41*	0·01–0·14 *0·10*	0·31–0·79 *0·49*	2·22–2·86 *2·67*
March	0·01–0·21 *0·11*	0·15–0·47 *0·27*	0–0·15 *0·06*	0·34–0·64 *0·14*	2·60–4·07 *3·50*
April	0–0·08 *0·02*	0·07–0·29 *0·15*	0·02–0·10 *0·06*	0·19–0·49 *0·31*	2·88–4·01 *3·45*
May	0·11–0·61 *0·20*	0·27–0·57 *0·43*	0·32–0·61 *0·41*	0·25–0·64 *0·43*	1·60–2·81 *2·43*
June	2·51–3·89 *3·13*	1·46–2·89 *2·19*	1·06–2·50 *1·54*	0·90–1·49 *1·12*	0·95–1·61 *1·21*
July	9·25–13·39 *11·88*	5·97–9·00 *7·14*	6·15–8·70 *7·20*	3·71–6·13 *4·60*	1·53–2·76 *1·98*
August	8·10–12·41 *9·17*	4·91–7·55 *6·36*	5·50–8·56 *6·47*	3·74–5·30 *4·47*	1·57–2·88 *1·93*
September	5·27–8·09 *6·60*	1·71–4·60 *3·00*	1·63–2·90 *2·18*	0·41–1·39 *0·87*	0·82–1·53 *1·21*
October	0·07–1·04 *0·39*	0–0·06 *0*	0–0·17 *0·05*	0–0·10 *0*	0·39–1·02 *0·79*
November	0 *0*	0 *0*	0 *0*	0 *0*	0·03–0·37 *0·14*
December	0–0·09 *0*	0–0·13 *0·06*	0–0·13 *0·06*	0·07–0·39 *0·22*	0·52–1·35 *1·00*

Month.	Leh	Peshawar	Quetta	Jacobabad	Karachi.
January	0·24–0·34 *0·29*	0·68–1·57 *1·10*	0·85–1·98 *1·51*	0·03–0·17 *0·06*	0·06–0·32 *0·17*
February	0·16–0·28 *0·25*	0·81–1·48 *0·95*	1·13–2·00 *1·58*	0·02–0·12 *0·07*	0–0·11 *0·02*
March	0·12–0·30 *0·17*	1·34–2·17 *1·63*	1·14–1·76 *1·29*	0·02–0·15 *0·07*	0–0·02 *0*
April	0·07–0·17 *0·13*	0·89–1·66 *1·18*	0·39–0·96 *0·71*	0–0·09 *0·01*	0 *0*
May	0·10–0·20 *0·14*	0·25–0·60 *0·45*	0·05–0·37 *0·17*	0–0·01 *0*	0 *0*
June	0·07–0·17 *0·12*	0·07–0·20 *0·12*	0–0·04 *0*	0 *0*	0–0·02 *0*
July	0·21–0·48 *0·35*	0·48–1·29 *0·78*	0·02–0·32 *0·14*	0·22–0·81 *0·46*	0·33–2·70 *1·25*
August	0·26–0·57 *0·41*	0·90–1·83 *1·20*	0–0·15 *0·02*	0·14–1·00 *0·49*	0·34–1·18 *0·69*
September	0·02–0·07 *0·04*	0·30–0·79 *0·57*	0 *0*	0 *0*	0–0·06 *0·01*
October	0–0·04 *0·01*	0–0·12 *0·06*	0 *0*	0 *0*	0 *0*
November	0–0·02 *0·01*	0–0·05 *0*	0–0·07 *0·03*	0 *0*	0 *0*
December	0·05–0·14 *0·11*	0·08–0·48 *0·39*	0·26–0·91 *0·49*	0–0·02 *0*	0–0·02 *0*

TABLE I.—*contd.*

Monthly median rainfall (in ins.) and 5 per cent interval.

Month	Ahmadabad	Nagpur	Poona	Hyderabad (Dn.)	Bangalore
January	0 *0*	0 -0 12 *0 03*	0 *0*	0 *0*	0—0 03 *0*
February	0 *0*	0 12 - 0 33 *0 19*	0 *0*	0—0 19 *0 01*	0 *0*
March	0 *0*	0 06 0 37 *0 17*	0 *0*	0 0 13 *0 02*	0 02–0 30 *0 09*
April	0 *0*	0 05 0 20 *0 11*	0 01 0 32 *0 15*	0 27 -0 87 *0 57*	0 76 1 29 *0 95*
May	0 0 10 *0 01*	0 23 0 77 *0 [illegible]*	0 21 1 43 *0 [illegible]*	0 37 0 92 *0 19*	3 72 4 51 *4 1[illegible]*
June	2 37 3 47 *2 6[illegible]*	7 35 9 32 *8 07*	3 31 5 08 *4 [illegible]*	2 89 4 91 *4 0[illegible]*	2 36—3 07 *2 71*
July	9 24 12 73 *1[illegible]*	12 42 14 8[illegible] *1[illegible]*	5 23 6 60 *[illegible]*	5 40– 6 98 *6 [illegible]*	3 40 4 16 *3 86*
August	5 45 8 40 *7 12*	8 57 11 18 *9 26*	2 62 3 67 *3 19*	4 10 6 68 *5 18*	4 35 6 13 *5 [illegible]*
September	2 66 4 66 *3 27*	5 [illegible] [illegible] 10 *6 [illegible]*	3·39 5 59 *4 60*	5 62 7 50 *6 [illegible]*	5 13 6 93 *5 85*
October	0– 0 12 *0*	0 [illegible] [illegible] 04 *1 02*	2 01 3 23 *2 71*	1 11 [illegible] 62 *2 [illegible]*	4 81 6 25 *5 [illegible]*
November	0 *0*	0 0 09 *0*	0 16 0 69 *0 39*	0 22 1 47 *0 83*	1 10- 1 58 *1 31*
December	0 *0*	0 0 16 *0*	0 *0*	0 *0*	0 11 0 28 *0 20*

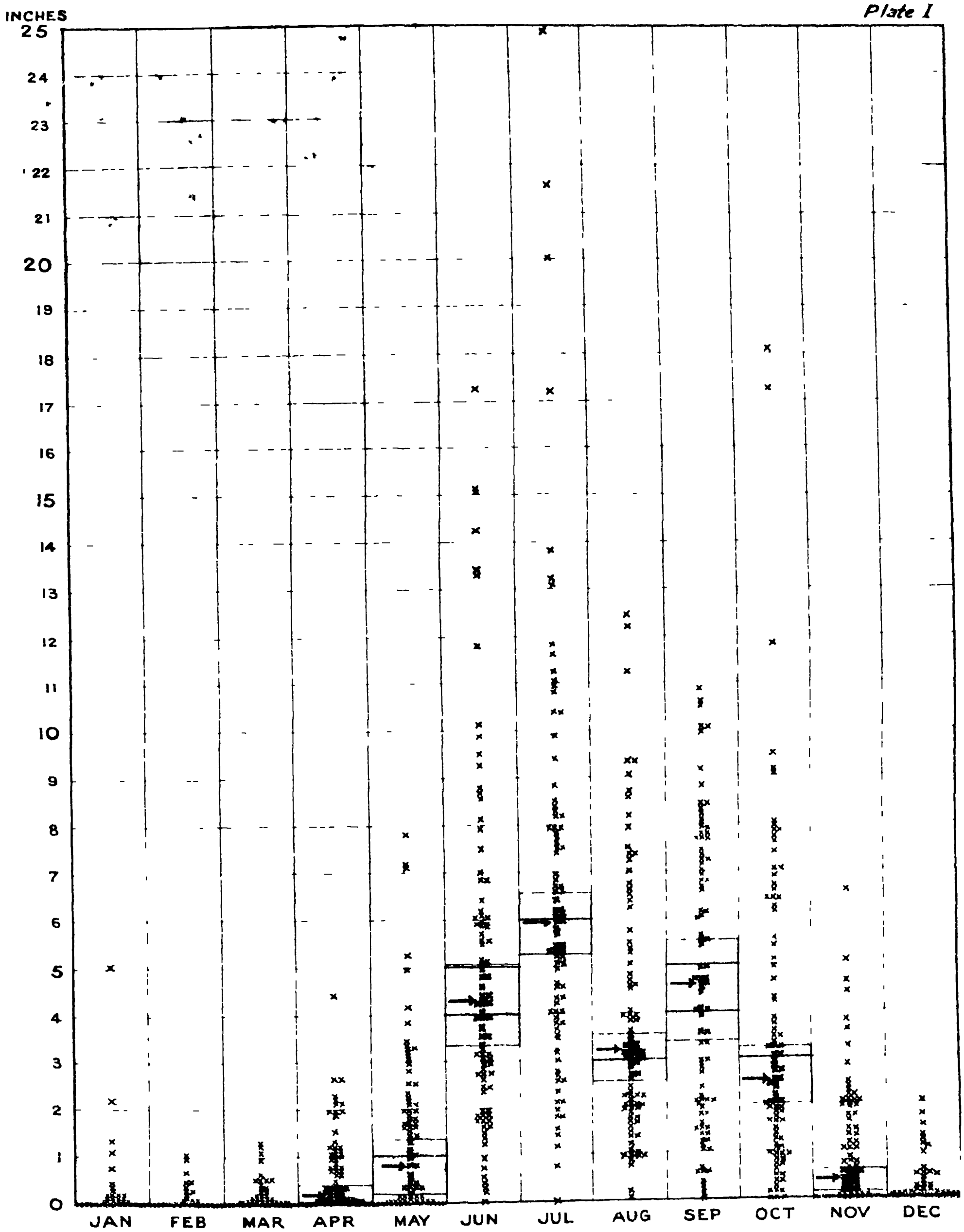
Month	Kodaikanal	Bombay	Karwar	M[illegible]	Trivandrum.
January	1 38 3 40 *1 [illegible]*	0 *0*	0 *0*	0 *0*	0 22 0 92 *0 15*
February	0 25 -1 52 *0 72*	0 *0*	0 *0*	0 *0*	0 09 -0 79 *0 25*
March	0 73 1 78 *1 21*	0 *0*	0 *0*	0 *0*	0 48 1 20 *0 79*
April	3 17 4 86 *4 09*	0 *0*	0 02 0 09 *0 0[illegible]*	0 [illegible] 1 16 *0 81*	2 99 4 46 *3 77*
May	5 34 7 38 *6 40*	0 0 04 *0 01*	0 62 2 52 *1 24*	3 11 5 18 *3 97*	4 44 7 78 *5 73*
June	2 54– 5 28 *3 65*	16 66 21 72 *18 92*	32 36 40 93 *35 60*	33·97 -39 28 *37 24*	10 60– 14 56 *13 21*
July	3 24 -5 15 *3 81*	21 82 24 83 *23 63*	33 03 42 36 *38 93*	33 72 40 48 *35 81*	6·48 8 86 *7 73*
August	4·05 6 78 *5 63*	10 70 15 03 *12 57*	17 18 22 11 *18 25*	18 72 23 39 *21 77*	2 87– 5 52 *3 97*
September	4 94 8 97 *6 66*	7 72 - 10 10 *8 59*	8 31 12 85 *10 25*	8 86 11 46 *10 34*	2 74—5 58 *3 98*
October	7 11 12 19 *10 73*	0·47 -1 17 *0 74*	3 48 6 20 *5 27*	5 54 -9 36 *7 10*	8 44—12 73 *9 58*
November	7 14 - 10 92 *8·65*	0 - 0 12 *0 02*	0 80–1 86 *1 [illegible]*	1·49 -2 53 *1 96*	4 65- -7 61 *5 91*
December	3 29 6 01 *4 80*	0 *0*	0 *0*	0– 0 21 *0 04*	1·09- - 3·56 *2 07*

TABLE I.—*concld.*

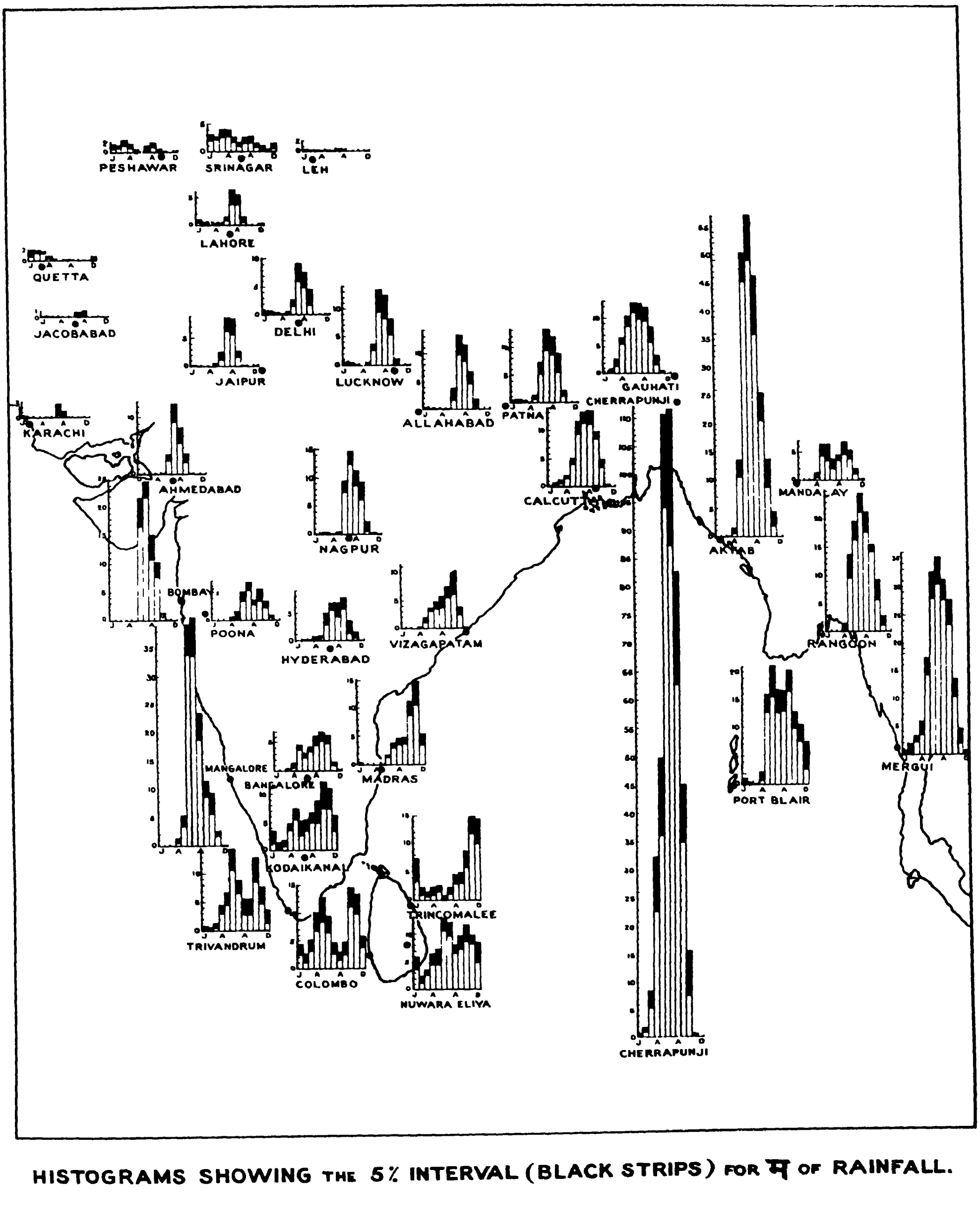
Monthly median rainfall (in ins.) and 5 per cent interval.

Month.	Madras.	Vizagapatam.	Colombo.	Trincomalee.	Nuwara Eliya.
January ..	0·13—0 52 *0 33*	0—0·06 *0*	2 32—4·10 *2 94*	3·12—7·14 *4·99*	3 57—5 75 *4 09*
February ..	0 0	0—0·08 *0*	1·03—2 65 *1 87*	0·94—2 12 *1 65*	1 08—2 43 *1·57*
March ..	0 *0*	0—0·06 *0*	2·99—5 07 *4·05*	0 69—1 65 *1 14*	2 65—3 77 *3 09*
April	0—0 07 *0 02*	0·10—0 29 *0 13*	6 74—10·00 *8 77*	0·90—2 30 *1 29*	4 17—6 15 *5 31*
May	0·08—0 39 *0 26*	0·95—2·00 *1 45*	8·31—12 77 *10 45*	1·46—2 53 *1 87*	4 39—7 16 *5 40*
June	1 25—1 89 *1 63*	3 00—3 68 *3 16*	6 22—9·43 *7 89*	0 34—1 05 *0 72*	10 53—12 90 *11 80*
July	2·89—3 79 *3 27*	3 51—4 81 *4 09*	2 51—4 58 *2·95*	1·05—2·20 *1 75*	9 46—12 08 *10 76*
August	3 31—4 67 *4 10*	3·71—5 80 *4·77*	1·39—2 95 *1 86*	2 61—4 45 *3 31*	6 48—7 94 *7 34*
September ..	3 27—4 86 *3 96*	5·42—7·39 *6 09*	2·58—4 57 *3 87*	2·87—4 97 *3 75*	7·04—9 57 *8 33*
October ..	8 57—11·08 *9 64*	6 01—10·14 *8·39*	10·93—14 36 *13 27*	6 69—8 62 *7·89*	8 68—11 51 *10 27*
November ..	10·56—14 66 *11 99*	2·31—3·82 *3 23*	9 62—13 26 *11 58*	11 66—14 98 *13 04*	7·98—9 65 *9 08*
December ..	3 19—5 36 *4 02*	0—0 10 *0 03*	3·64—5·73 *4·44*	9 70—14 28 *11 05*	4 71—8 44 *5 87*

M37DGO .—425—26 7-39—GIPS

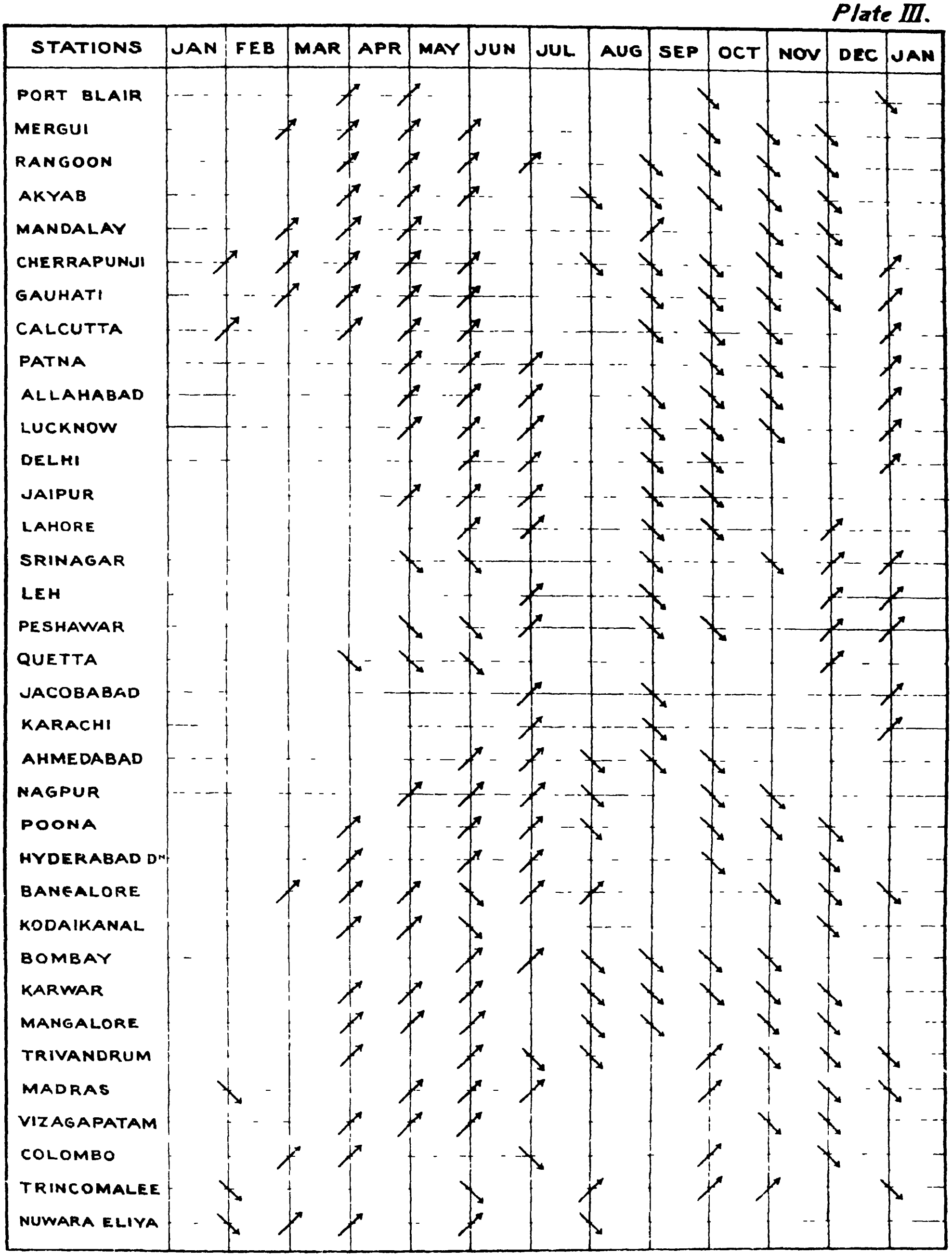


RAINFALL DISPERSION DIAGRAM FOR POONA.



HISTOGRAMS SHOWING THE 5% INTERVAL (BLACK STRIPS) FOR म OF RAINFALL.

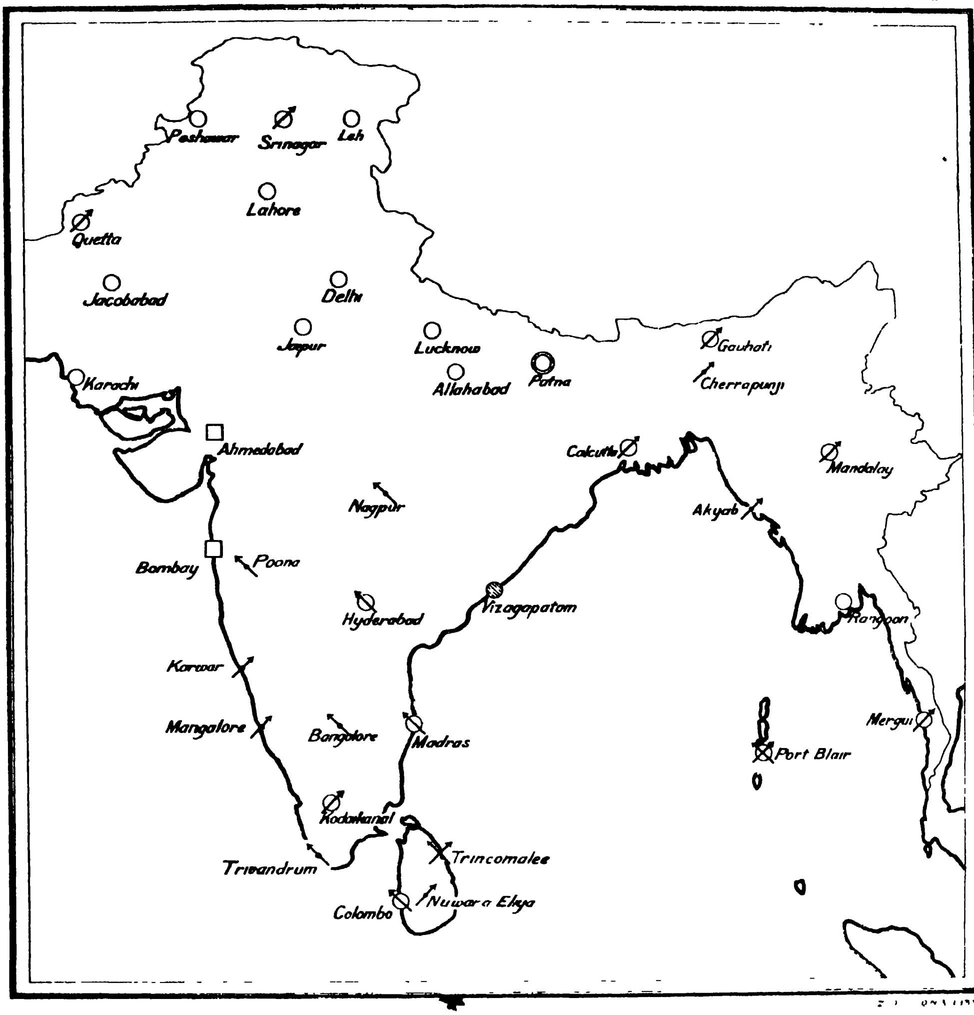
Plate III.



RAINFALL DISCONTINUITIES BETWEEN ADJACENT MONTHS
ON THE 5% LIMIT FOR RANDOM CHANCE

G P Z O POONA 1939

Plate IV



EXPLANATION OF SYMBOLS

No significant difference in rainfall amount between June and July

" " " " " " July and August

" " " " " " August and September

Even distribution of rainfall in June, July and August

" " " " July August and September

" " " " " June to September

Progressive increase in rainfall from June to October

" decrease " " " July to September

Discontinuity in rainfall amount between each of the months June, July August & September

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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Vertical currents in the first few kilometres over Poona and their possible effect on the measures of upper winds made by pilot balloons assumed to rise at a known constant rate.

BY

K. P. RAMAKRISHNAN.

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VERTICAL CURRENTS IN THE FIRST FEW KILOMETRES OVER POONA AND THEIR POSSIBLE EFFECT ON THE MEASURES OF UPPER WINDS MADE BY PILOT BALLOONS ASSUMED TO RISE AT A KNOWN CONSTANT RATE.

BY

K. P. RAMAKRISHNAN.

(*Received on 2nd February 1938*)

Summary.—The height-time curves of both morning and afternoon pilot balloon ascents at Poona on a large number of days in May and November 1937 determined by the tail method are compared with those deduced from the formula $A = 84 \dfrac{L^{\frac{1}{2}}}{(L+W)^{\frac{1}{3}}}$. For a few of these ascents, the winds worked out from the two sets of height values are compared. The method of calculation of winds is examined and it is shown that no simple correction can be applied to the wind values so as to allow for the effect of vertical currents.

A statistical comparison has been made of one year's data of the rates of ascent in the first 4 km obtained by the tail method and by the above formula. It is found that the two rates agree well in the mornings, while, in the afternoons, wide variations occur, which on the aggregate amount to an excess of rate of ascent of about 12%, the increase being more pronounced in the months February to June.

Brief resumés of previous unpublished work on the subject are given. In an appendix, it is shown that errors due to slant of tail cannot account for as much deviations as actually occur.

Introduction.

In the routine measurement of upper winds by means of pilot balloons, most meteorological services assume that the balloons rise at a constant rate, although the rates of ascent are computed from slightly different formulæ, due to Dines, Hesselberg, Birkeland and others [1]. In a tropical country like India, vertical currents may considerably affect the results obtained, if the heights are calculated on the basis of a constant rate of ascent, particularly in the afternoons. (Some instances of such currents have been described by Field, Ramanathan and the author) [2 to 4]. In the India Meteorological Department, the tail method has therefore been used since regular upper wind measurements were started in 1914. In recent years, the demand has been growing from aviation interests for upper winds at comparatively short notice and the question as to the amount of error that may be expected if a constant rate of ascent is assumed has been under consideration. The solution of the question has become urgent as a self-recording theodolite working

on the basis of uniform rate of ascent of the balloon is now available in the market and has begun to be used at a few of the observatories in India for ascents made at night.

Previous work.

A limited examination of the question with respect to some data collected at Madras during the period December 1934 to February 1935 was made by Dr. K. Das. The winds at Madras were measured by ascents of both tailed and tailless* balloons, these being made within a few minutes of each other.

The ascents were made in the mornings on 35 days and in the afternoons on 30 days. In an unpublished report of the results, Das found that the mean differences of wind direction and speed between the two methods were about 10° and 2m/s respectively. He also found that the differences in the afternoon were only slightly greater than those in the morning. This is probably due to the fact that the ascents were made in the cold season.

As has been mentioned, clear evidence of the existence of vertical currents and consequent abnormal rates of ascent of pilot balloons has been available for several years. In Poona, for some years past, systematic attempts have been made to make use of the routine (tailed) ascents to collect information about these currents. As the accuracy of such information depends on the accuracy of determining heights reached by tailed pilot balloons and as one of the chief sources of error in height-calculation by the tail method is due to slant of tail, it was sought to reduce errors due to this by weighting the tail, which could be done only for some time.

V. V. Kanade who worked under Dr. K. R. Ramanathan made a partial analysis of pilot balloon ascents at Poona of 1933 and 1934 from this point of view ; he could not, however, complete the work. A small selection of height-time curves made by Kanade where the points showed a close fit and where the angles of elevation were mostly below 60° is given in *Fig. 1 a*†. Some values of the angle of elevation are written along the height-time curves. All the instances selected were ascents in the afternoon, and the weight and free lift were such that the expected rate of ascent was 9·2 km/hr. The diagram clearly shows that considerable departures from the expected rates of ascent do occur in the afternoons in all the months from March to November.

During the periods February to June 1935 and November 1935 to January 1936, the usual pilot balloons at Poona had weights of 30 gms each attached to the tail. The vertical angles and the angles subtended by the tail were read at intervals of half a minute for the first 15 minutes. The plotted points of height and time of these weighted ascents fit into a smooth curve ; a few examples are reproduced in *Fig. 1 b*.

Data now available.

From 1st February 1936, at Poona, as well as at all other pilot balloon stations in India, different kinds of balloons are being given such free lifts that the expected

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* The rates of ascent of the tailless ascents were calculated from the formula

$$A = 84 \frac{L^{\frac{1}{2}}}{(L+W)^{\frac{1}{3}}}$$

where A is the rate of ascent in metres per minute,
L the net free lift of the balloon, and
W the weight of the balloon.

† The data collected by Mr. V. V. Kanade were kindly placed at my disposal by Dr. K. R. Ramanathan.

rates of ascent have always the same values for each kind of balloon. Moreover, from 1st April 1937, afternoon ascents have become a regular feature at Poona. The routine pilot balloon ascents of these recent times are thus more suited for the collection of information about vertical currents. The balloons, however, are not weighted and hence errors due to tail slant are not entirely absent. The expected rates were calculated from the formula—

$$A = 84 \frac{L^{\frac{1}{2}}}{(L+W)^{\frac{1}{3}}},$$

where A is the rate of ascent in metres per minute,

L the net free lift, *i.e.*, the free lift measured before string and flags were attached *minus* the combined weight of the string and flags, and

W the combined weight of the balloon, string and flags.

The balloons had weights varying from 20 to 60 gms. The formula used, it will be seen, is that of Dines,[1] extended to tailed balloons on the assumption that the addition of the string and flags is equivalent to the addition of a similar weight to the material of the balloon. It does not allow for any change of the constant 84 due to the addition of the string and flags. Experimental verification of these assumptions is very desirable.

Some individual height-time curves compared with expected ones.

The paper by Ramanathan and the author[4] already referred to gives some instances of vertical currents; but these were shown by balloons that were specially let off with almost no free lift. The doubt will arise whether the currents are strong enough to manifest themselves in the usual pilot balloon ascents. Further, the ascents being on selected days, do not show how frequently such currents occur.

The actual and expected height-time curves of both morning and afternoon ascents at Poona on a number of *successive* days in May and November, 1937 are given in *Fig. 2*. In this figure, no selection of days on which the currents were pronounced has been made. A few days happen to be omitted in May, because on these days balloons made of guttapercha were used for which the empirical formula mentioned before is not applicable. The height corresponding to each instant of observation is shown by a blackened or hollow circle (these two symbols being used to prevent confusion between points referring to adjacent days); the smoothed actual height-time curves through these points are shown by thick curves; and the expected height-time curves by thin straight lines. *Fig. 2* unmistakably shows that on most afternoons, and a few mornings, considerable departures from the expected rates of ascent occur, particularly in the first 3 km. These departures are apparently not confined to the hot weather months like May, but occur even in the cooler months like November.

Although the individual points in *Figs. 1* (*a*) and *2* are not free from errors due to tail slant, the more important features of the *smoothed* height-time curves in them must be practically free from these for the following reasons :—

1. The individual points fit the curves with remarkable closeness, which is very unlikely with casual errors;

2. The smoothed curves for the mornings agree very closely with the expected curves ; and it is only in the afternoons, that they show large deviations from the expected ones ;

3. As can be seen from the *Appendix*, errors due to tail slant cannot account for such large deviations as often occur.

Statistical comparison of the actual and expected rates of all ascents of one year.

The comparative data of actual and expected rates of ascent of one year (from 1st February 1936 to 31st January 1937) have also been examined statistically. As it is desirable to base a complete statistical analysis on data for at least a few years, only the main results of this preliminary examination are given here.

Table 1 gives the frequencies (number and percentage) of occurrence of different values of actual/expected rate of ascent for the layer 0-4 km (above ground) at Poona during the period February 1936 to January 1937.

TABLE 1.

Range of actual/expected rate of ascent	Morning.		Afternoon.	
	Number.	Percentage.	Number.	Percentage.
0·71—0·90	12	5	3	3
0·91—1·10	235	93	46	51
1·11—1·30	6	2	30	33
>1·30	..		11	12

The difference between the figures for the morning and afternoon is striking.

The highest value of actual/expected rate recorded on any day over a whole kilometre was 2·3 and the lowest 0·4 ; the corresponding values for the entire 4 km-layer were 1·7 and 0·7 respectively.

The mean values of actual/expected rate for the whole year were 0·99 for the morning and 1·09 for the afternoon; the difference between morning and afternoon was more pronounced in the months February to June, for which period, the values were 1·00 and 1·14. It thus appears that, on the aggregate, in the first 4 km at Poona the rate of ascent in the afternoon is about 10 to 12% higher than that in the morning.

Examination of the rates prevailing in different height-steps shows that in the morning, the rate of ascent is slightly higher in the layer 2—4 km than in the lower 2 km, whereas in the afternoon, the rate is highest in the first kilometre, diminishes to a minimum in the layer 2—3 km and increases again.

The effect of departures of the rates of ascent from the expected values on the wind directions and speeds at particular levels.

Since the directions and speeds of wind at various levels are derived from the heights reached and the angles of elevation, their values also will show appreciable differences depending on whether a uniform rate of ascent based on a semi-empirical formula is used or the heights are actually worked out by the tail or two-theodolite method. It is also clear that these differences will increase with the difference between the actual and expected rates of ascent. In order to give an idea of the magnitude of these differences in a few actual instances, the trajectories worked out from each of the sets of height values for six of the ascents shown in *Fig. 2* are given in

Fig. 3. The directions and speeds at standard levels deduced from the two sets of trajectories are given in *Table 2.*

TABLE 2.

Comparison of the directions and velocities deduced from determinations of height by the tail method (ordinary type) *with those deduced by the assumption of a uniform rate of ascent depending on the weight and free lift (in italics) on selected days.*

Date.	1·0 km A.S.L		1·5 km		2·0 km		3·0 km		4·0 km		6·0 km	
	D (°)	V (km/hr)	D (°)	V (km/hr)	D (°)	V (km/hr)	D (°)	V (km/hr)	D (°)	V (km/hr)	D (°)	V (km/hr)
10-5-37 ..	160	5	150	5	140	6	130	7	170	11	250	17
(afternoon)	*170*	*7*	*150*	*5*	*150*	*8*	*120*	*8*	*150*	*9*	*160*	*10*
13-5-37 ..	350	11	10	6	350	16	360	11	10	9		..
(afternoon)	*340*	*12*	*350*	*25*	*10*	*13*	*10*	*26*	*10*	*35*	*220*	*46*
14-5-37	310	10	310	28	320	19	50	16	60	26	18	32
(afternoon) ..	*310*	*15*	*330*	*9*	*60*	*10*	*70*	*18*	*180*	*16*	..	..
7-11-37 ..	100	16	60	16	70	23	90	28	110	26	140	26
(afternoon)	*60*	*10*	*70*	*17*	*90*	*21*	*110*	*29*	*110*	*26*	*160*	*28*
15-11-37	130	16	90	17	90	27	30	11	320	12	230	11
(morning)	*140*	*22*	*130*	*31*	*90*	*23*	*10*	*8*	*320*	*14*	*210*	*15*
20-11-37	110	9	240	5	190	8		.	.	..	270	31
(afternoon) ..	*120*	*4*	*180*	*6*	..				*270*	*23*		

The figures in *Table 2* show that very divergent results may sometimes be given by the assumption of a uniform rate of ascent of the balloon.

At first, it may appear possible to correct the wind directions and speeds for the difference in the rate of ascent in some simple manner. Closer consideration will, however, show that this is not so.

Example 1.—*The actual rate of ascent bears a constant ratio to the expected or normal rate of ascent.*—Let r be the anticipated rate of ascent and xr the actual rate, both assumed uniform. Consider the position of the balloon at two instants n_1 and n_2 minutes after start. Let the angles of elevation at the two instants be E_1, E_2 respectively.

Let A, B (Fig. 4) represent points vertically below the balloon at n_1 and n_2 minutes, A', B' those below the positions it would have occupied at the same instants if the rate of ascent had been normal, and O the point of observation. Since the angles of azimuth at the two instants are measured quite independently of the heights reached, O, A and A' are collinear ; so are O, B and B'.

Now,

$$OA = \frac{n_1 x r}{\tan E_1} \quad ; \quad OB = \frac{n_2 x r}{\tan E_2}$$

$$OA' = \frac{n_1 r}{\tan E_1} \quad ; \quad OB' = \frac{n_2 r}{\tan E_2}$$

$$\therefore \quad \frac{OA}{OA'} = x = \frac{OB}{OB'}$$

Hence the triangles OAB and $OA'B'$ are similar. It follows that $A'B'$ is parallel and proportional to AB. Since the vectors $\overline{AB}$ and $\overline{A'B'}$ represent the winds, it

follows that the wind between *any two instants* obtained by assuming a uniform rate of ascent will have the same direction as, and will bear a constant ratio to, that obtained between the same two instants from the actual height-time curve. Owing to the variation of wind with height, however, the winds *at the same level* obtained from the two methods which will correspond to different instants in the two cases will not be related in such a simple manner ; and will show large differences near levels where the rate of variation of wind with height is large.

Example 2.—*The actual rate differs considerably from the anticipated one for a certain period, but becomes equal to it later.*—Consider the positions of the balloon at the end of n_1 and n_2 minutes in the part where the two rates of ascent are equal. Let the actual heights be h_1 and h_2 and the anticipated heights H_1 and H_2 (Fig. 5). It follows that $(H_2—h_2) = (H_1—h_1)$.

Let O (Fig. 6) represent the starting point and A, B points vertically below the balloon at the end of n_1 and n_2 minutes respectively.

The wind from n_1 and n_2 obtained from the actual height-time curve will be represented by the vector $\overline{AB}$.

Let A', B' be the points vertically below the positions the balloon would have been expected to take at the end of n_1 and n_2 min. These will lie along the straight lines OA, OB respectively because the bearings of the balloon at the two instants with respect to O are known. The wind represented by the vector $\overline{A'B'}$ will be related numerically (in a simple way) to that represented by the vector $\overline{AB}$ only if OAB, $OA'B'$ are similar triangles, *i.e.* if $OA : OA' = OB : OB'$.

Let the angles of elevation of the balloon at n_1 and n_2 minutes be E_1 and E_2 respectively—

$$OA = \frac{h_1}{\tan E_1} \quad ; \quad OA' = \frac{H_1}{\tan E_1}$$

$$OB = \frac{h_2}{\tan E_2} \quad ; \quad OB' = \frac{H_2}{\tan E_2}$$

$$\therefore \frac{OA}{OA'} = \frac{h_1}{H_1}, \text{ and } \frac{OB}{OB'} = \frac{h_2}{H_2}$$

Suppose $OA/OA' = OB/OB'$.

It follows that $\dfrac{h_1}{H_1} = \dfrac{h_2}{H_2}$

$$\therefore \frac{H_1 - h_1}{H_1} = \frac{H_2 - h_2}{H_2}$$

But $H_1 - h_1 = H_2 - h_2$ and $H_1 \neq H_2$

Hence, $OA/OA' \neq OB/OB'$

The triangles OAB and $OA'B'$ are not similar and therefore the vectors $\overline{AB}$ and $\overline{A'B'}$ cannot be related in a simple numerical manner.

The argument holds good whether a balloon rises at an increased or decreased rate in the first part of its ascent.

Conclusion.

The examination of the height-time curves of pilot balloon ascents at Poona for over a year and the examination of the principles involved in the calculation of winds carried out in this paper lead to two conclusions :—

1. At Poona, vertical currents, sometimes ascending and sometimes descending, are often present in the afternoon ; occasionally, they occur in the morning. The rate is generally of the order of 3 to 5 km/hr, though, on rare occasions, it goes to about 10 km/hr.

2. Wind values at standard levels calculated on the assumption of a uniform known rate of ascent of the balloon may be affected considerably by departures of the rate of ascent from the expected value due to the presence of vertical currents; and no simple correction can be applied to these.

ACKNOWLEDGMENT.

I am very grateful to Dr. N. K. Sur for the encouraging interest taken by him in the work and to Mr. N. Sundaram for considerable help in the preparation of the tables and diagrams. I convey my thanks also to Drs. K. R. Ramanathan and K. Das for placing at my disposal material which they had collected ; and to Mr. G. Chatterjee and Dr. K. R. Ramanathan for some valuable suggestions.

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APPENDIX.

The order of magnitude of errors due to tail slant.

If a balloon rises at a rate V and there is a difference in the horizontal wind velocity between the level of the balloon and that of the tail v, the tail will depart from the vertical by an angle θ, where

$$\tan \theta = \frac{v}{V} \cdot$$

If the direction of the wind is the same at all heights, increase of speed with height will, by blowing the balloon farther away from the observer than the tail, cause a slant of tail towards the observer in the plane of sight ; decrease of speed with height will cause a slant of tail away from the observer.

If the wind changes its direction by 180° above a certain level, say, for example, a westerly wind changing to an easterly at higher levels, in the easterly current, the above relations will hold good only after the balloon has gone to the west of the observer. Till then, the opposite will hold good. In other words, an increase of easterly wind will have to be looked upon as a decrease of westerly wind so long as the balloon is to the east of the observer.

In practice, however, both direction and speed change with height.

Let B (Fig. 7) be the foot of the perpendicular from the balloon on the horizontal plane, and O the point of observation.

Let the vector $\overline{FB}$ (v) represent the difference (wind at the level of the balloon *minus* wind at the level of the flag). The tail will then make an angle $\theta = \tan^{-1} \frac{v}{V}$ with the vertical and lie in the vertical plane passing through FB. We shall call the angle OBF γ.

The slant of tail can be resolved into two components, one in the plane of sight by an angle $\delta = \theta \cos \gamma$ and the other at right angles to the plane of sight by an angle $\epsilon = \theta \sin \gamma$ The observer will be aware of the component of the slant at right angles to the plane of sight ; and its effect is to reduce the effective length of tail (l) to the value $l \cos \theta$. (The error on this score would have been eliminated if the total visual length of tail were estimated ; but as it is, the apparent length of tail is measured against a scale with horizontal graduations.) The observer will not be aware of the component of the tail slant in the plane of sight.

Fig. 8 represents the plane of sight. B represents the balloon, O the observation point, F the position of the flag, when there is no component of tail slant in the plane of sight, F' the position of the flag when there is a component of tail slant δ in the plane of sight towards the observer and F'' the position of the flag when there is an equal slant away from the observer.

Let E be the angle of elevation.

$$BF' = BF = BF'' = l \cos \epsilon.$$
$$F'BF = FBF'' = \delta$$
$$F'X' = l \cos \epsilon . \cos (E+\delta)$$
$$F''X'' = l \cos \epsilon . \cos (E-\delta)$$
$$FX = l \cos \epsilon . \cos E.$$

Let ω be the angular measure of the tail if there had been no tail slant in either plane ; and, ω', ω'' the angular measures corresponding to he position F' and F''

$$\frac{\omega'}{\omega} = \cos \epsilon . \frac{\cos (E+\delta)}{\cos E}$$

$$\frac{\omega''}{\omega} = \cos \epsilon \frac{\cos (E-\delta)}{\cos E}$$

Let h be the true height of the balloon.

$$h = \frac{l}{w} \sin E \cos E.$$

Let h' and h'' be the heights determined by the tail method in the cases represented by BF' and BF'' respectively.

$$h' = \frac{l}{w'} \sin E \cos E ; \frac{h'}{h} = \frac{\cos E}{\cos \epsilon \cos (E+\delta)}$$

$$h'' = \frac{l}{w''} \sin E \cos E ; \frac{h''}{h} = \frac{\cos E}{\cos \epsilon \cos (E-\delta)} .$$

The expressions for h' and h'' are really the same, and the one for h' itself can be used in all cases, provided the sign of δ is taken into consideration. δ will be positive whenever the angle FBO (Fig. 7) is acute and negative when the angle FBO is obtuse. However, when written in the two forms as above, it becomes more obvious that a component of tail slant in the plane of sight towards the observer will cause an overestimate and one away from the observer an underestimate of the height; the sideways component always causing an overestimate. The compounded effect of slants in various directions will therefore probably be a slight overestimate of the height.

In *Fig.* 9 are given (1) height-time curves according to the formula (straight lines) (2) the height-values that would have been obtained by the tail method if the balloon rose at the rate given by the formula and no vertical currents existed but the tail had slants due to variation of wind with height as described above (blackened circles) and (3) the height values that were actually obtained by the tail method (hollow circles) for two of the ascents included in *Fig.* 2, *viz.*, the afternoon ascents on 14-5-37 and 10-11-37. A smoothed curve has been drawn through the points mentioned in (3) only. The straight lines themselves seem to fit the points mentioned in (2) sufficiently well. It is clear that such deviations as occur cannot be due to slant of tail due to variation of wind height.

M25DGofOb,—425—17-4-39—GIPS

PLATE I

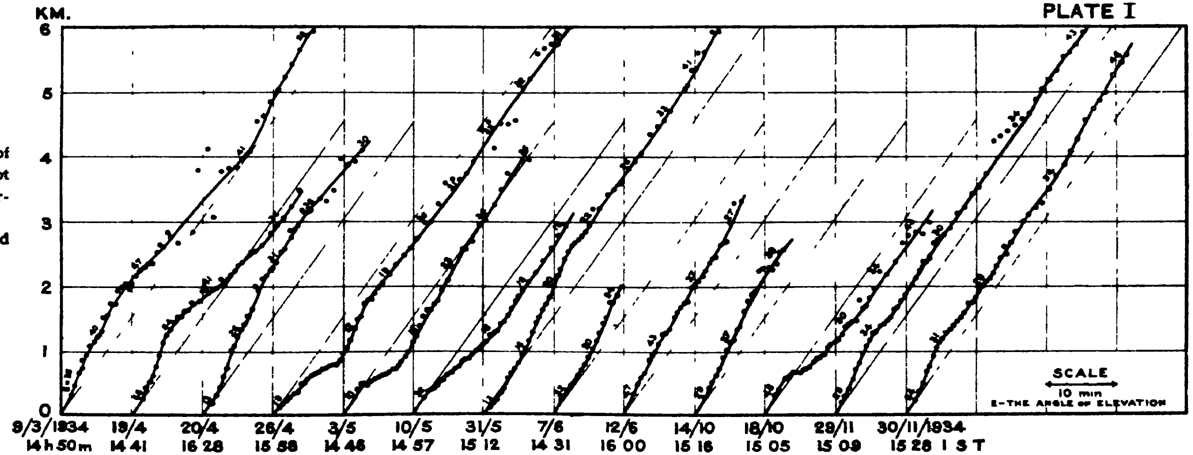

Fig 1a. Some examples of Height-Time Curves of Pilot Balloon Ascents in the afternoon at Poona.
compared with the expected ones (thin straight lines)
Selected by V V Kanade

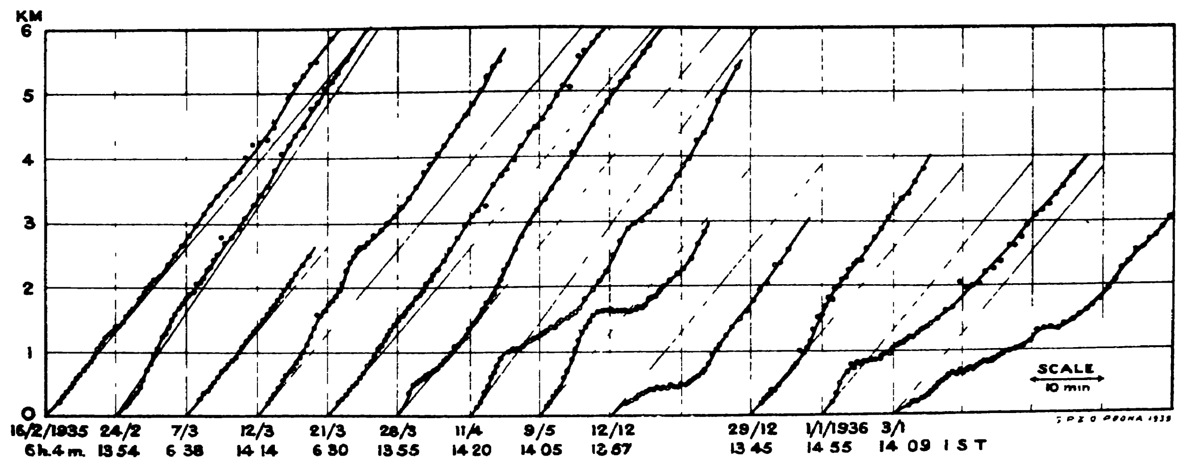

Fig 1 b Some examples of Height-Time Curves of *Weighted* Pilot Balloon Ascents at Poona
compared with the expected ones (thin straight lines)

PLATE II

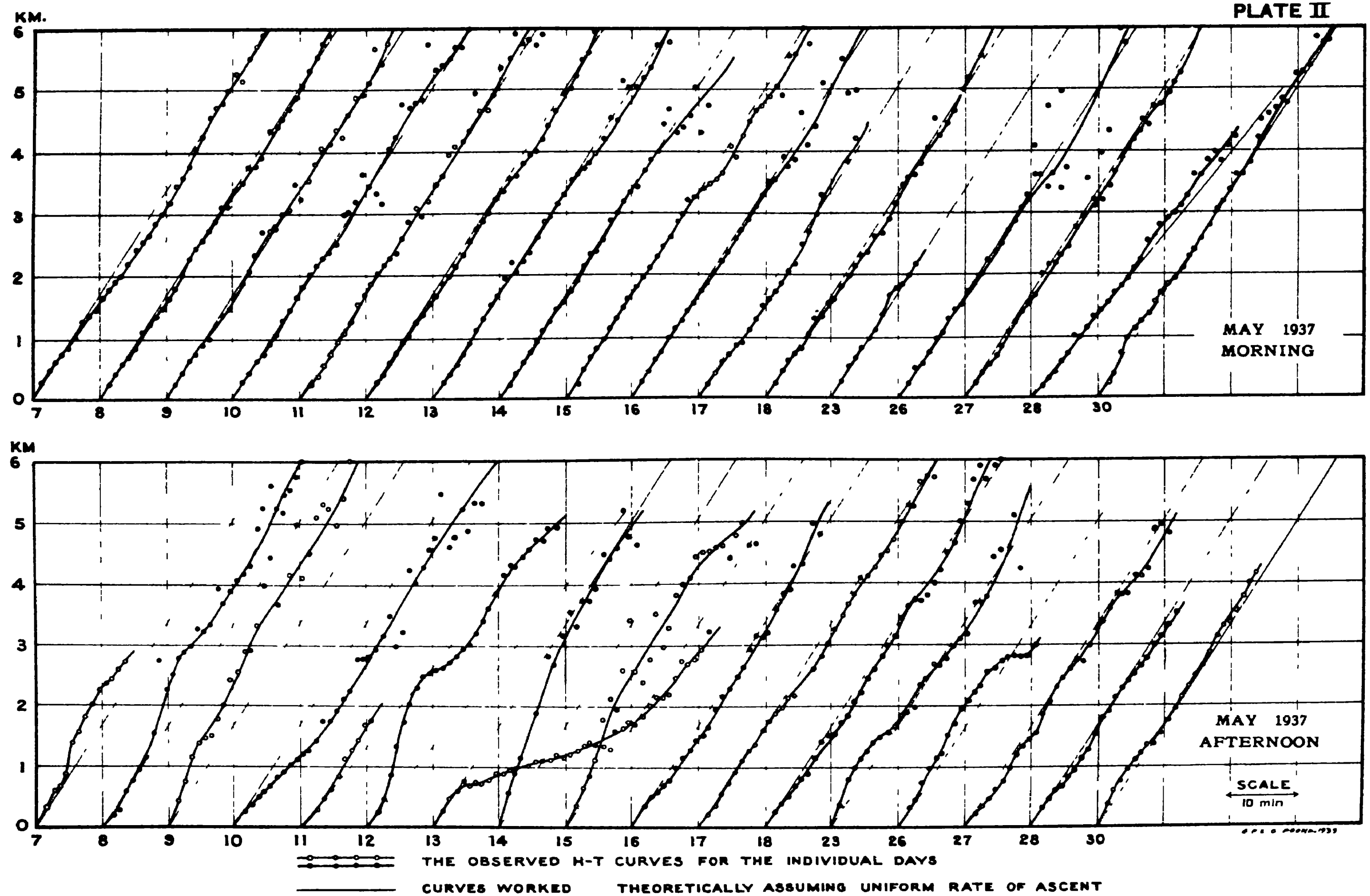

FIG. 2 (A) HEIGHT-TIME CURVES OF PILOT BALLOONS LET OFF FROM POONA

PLATE III

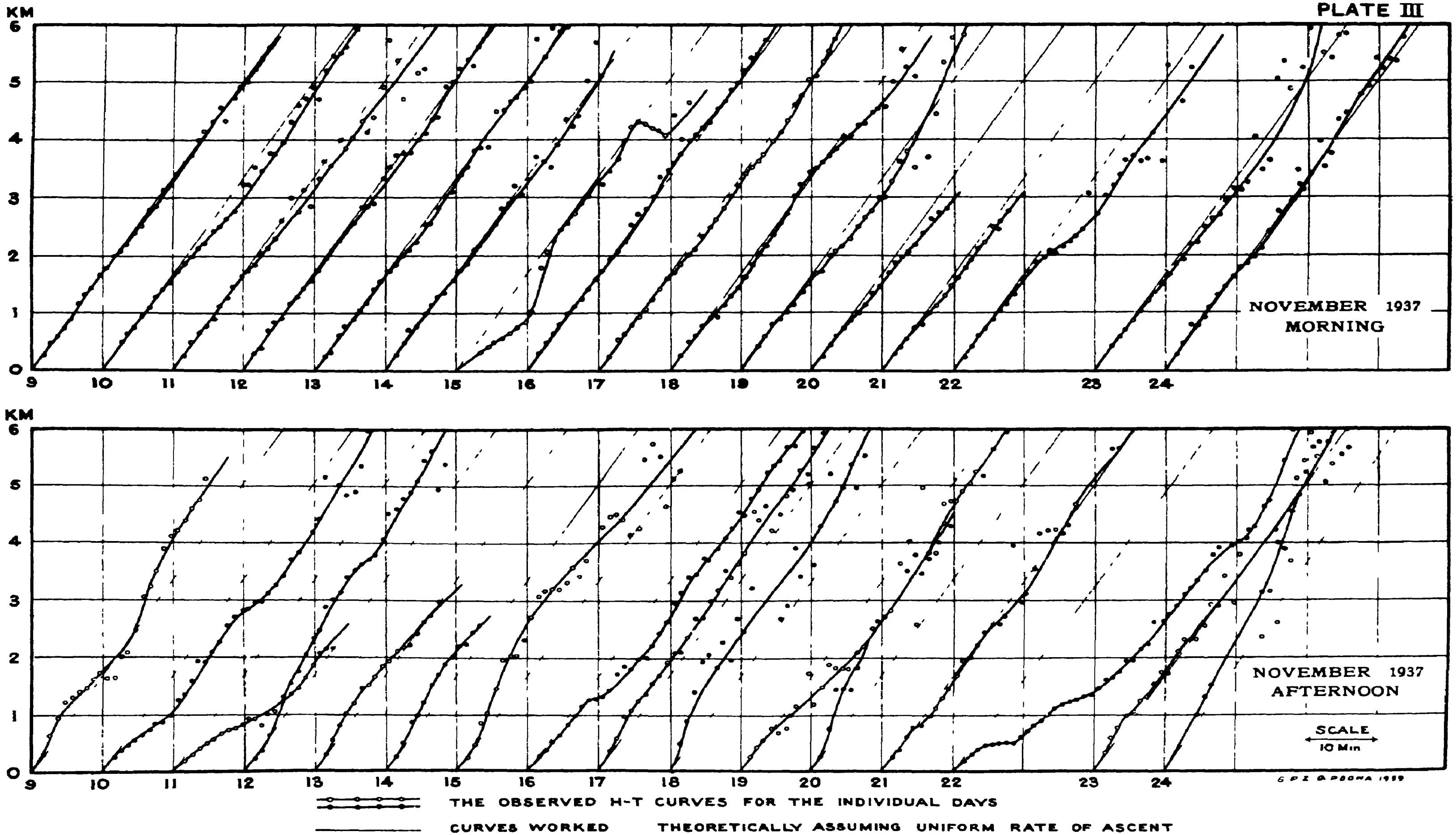

FIG. 2 (B) HEIGHT-TIME CURVES OF PILOT BALLOONS LET OFF FROM POONA

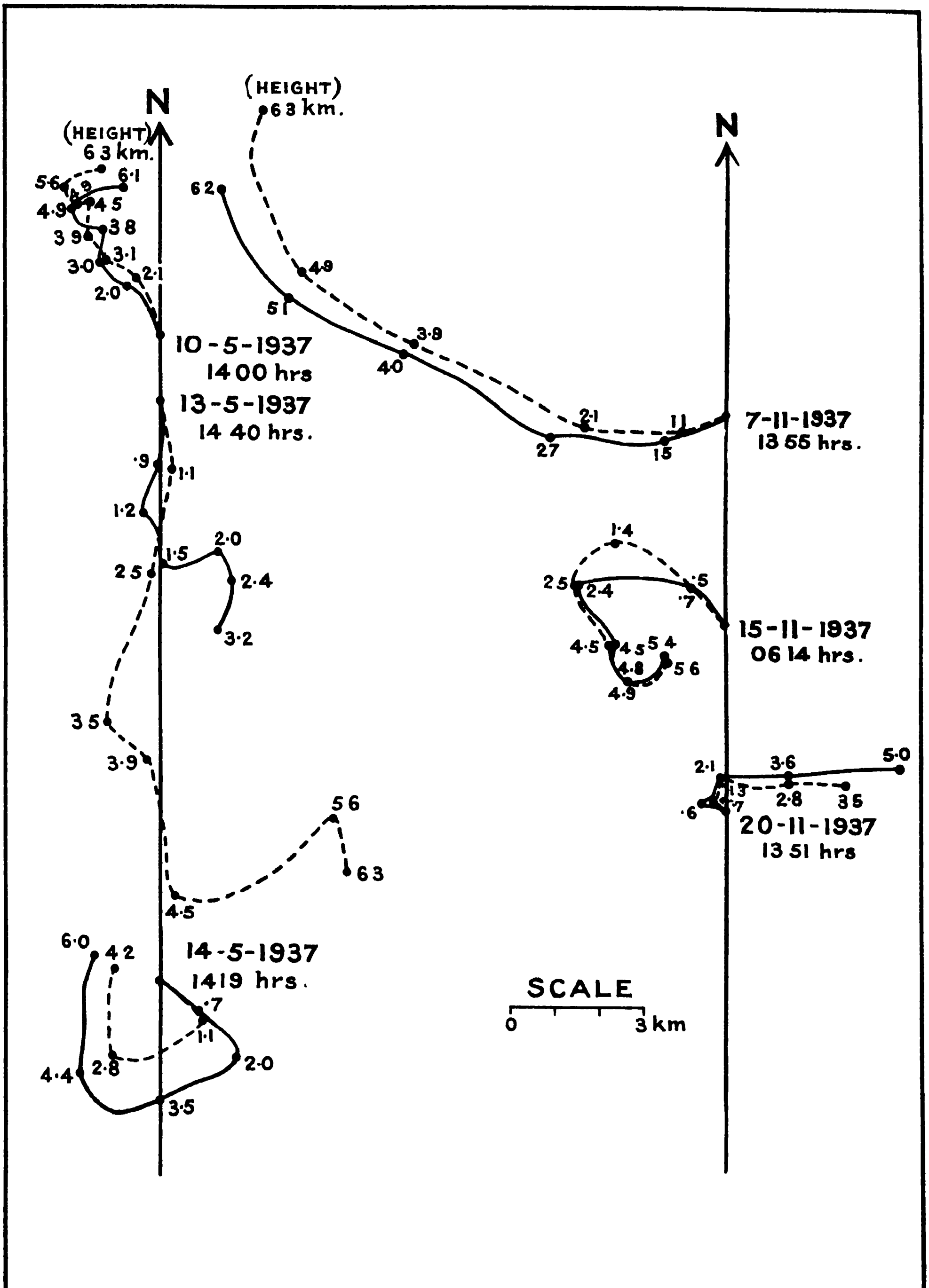

Fig. 3 Trajectories of selected pilot balloon ascents worked out both from heights determined by the tail method (————) and from those calculated from the formula (- - - - - - -).

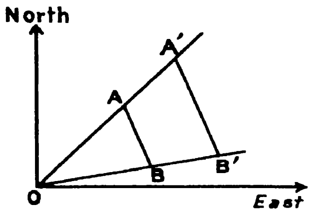

FIG. 4.

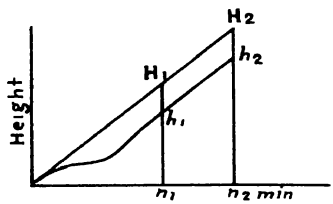

FIG. 5.

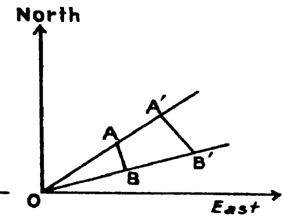

FIG. 6.

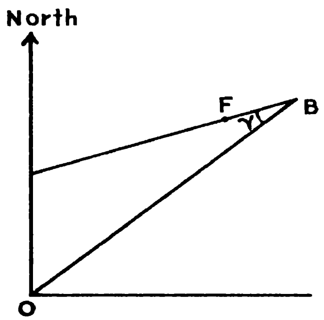

FIG. 7

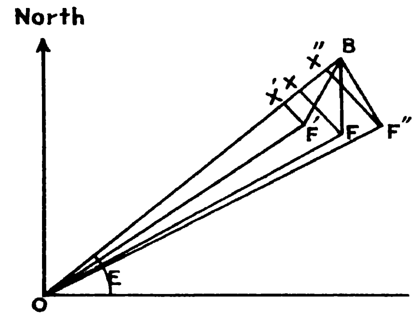

FIG. 8.

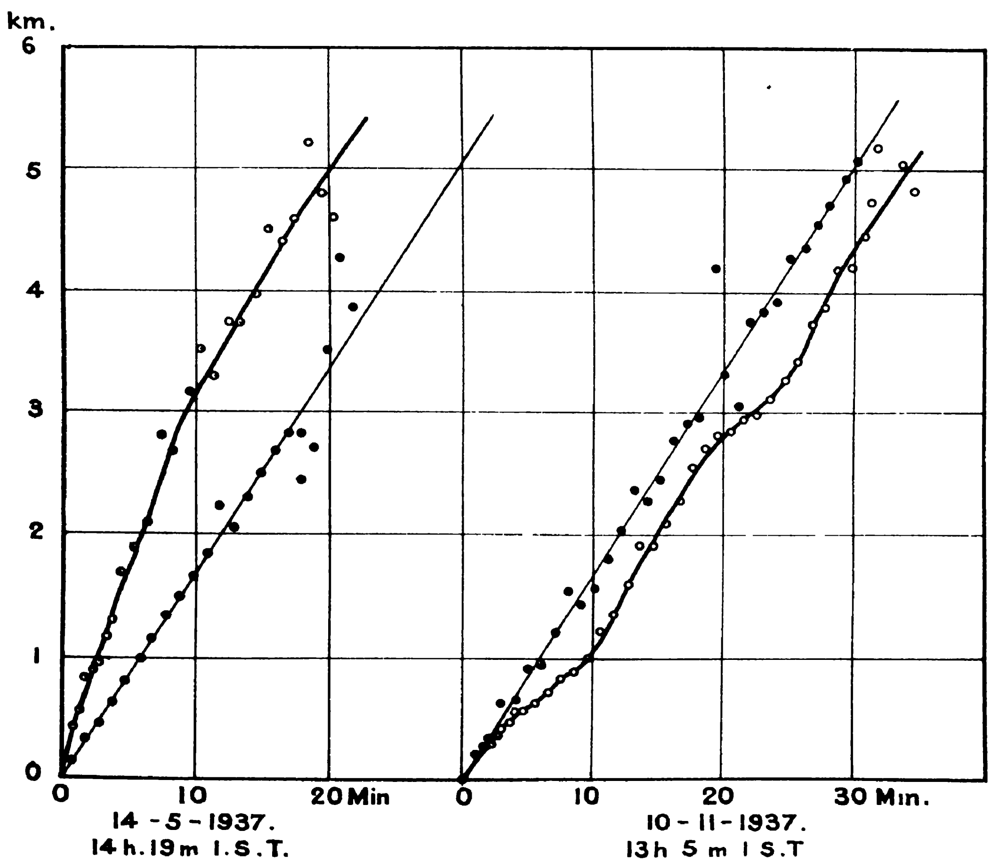

FIG. 9.

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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Atmospheric electric potential gradient, conductivity and air-earth current on electrically 'quiet' days at Colaba

BY

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Atmospheric electric potential gradient, conductivity and air-earth current on electrically 'quiet' days at Colaba

BY

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(*Received on 10th March 1937*).

Summary.—Observations of atmospheric electric conductivity carried out at Colaba with a Gerdien apparatus during the period July 1935 to August 1936 have been analysed for diurnal and seasonal changes and correlated with the associated values of potential gradient Values of air-earth current, computed from these quantities, are also discussed The results show that during non-monsoon months (October to part of May) conductivity is approximately inverse to potential gradient. The double oscillation of potential gradient during these months is related to the variation in smoke and nuclei concentration, caused predominantly by wind. This inverse relation almost ceases in monsoon (June to September) when the air supply is directly from the sea and the effect of local pollution is almost absent The diurnal curve of potential gradient in this period is essentially similar to that over the ocean. In all the seasons, one of the maxima of both potential gradient and air-earth current (18 h. to 19 h G.M.T) coincides approximately with the maximum of these elements over the oceans ; the mean values of the elements at Bombay are nearly equal to the mean ocean values.

Introduction.

The systematic recording of atmospheric electric potential gradient with a Cambridge Instrument Company's photographic recorder[8] was begun at Colaba in 1930. It is housed in a small room in the northeast of the observatory compound close to the sea-wall. For collecting the potential a radium spiral collector is used. It projects outside the room through a hole in the western wall at a height of 171 cm. above ground. Normally the distance between the middle of the radium spiral and the wall is 40 cm. but this is altered suitably if the potential gradient shows signs of any large abnormalities. The calibration of the electrograms used to be

done in the following manner before May 1936. An auxiliary ionium collector was installed so as to project outside the electrograph hut on the eastern side facing the sea through a hole in the middle of a plane sheet of zinc, 1·2 × 2·5 metres, which formed a continuation of the sea-wall. The same Dolezalek electrometer was used for measuring the potential and the two collectors were used alternately, one after the other. The potential gradient obtained with the collector towards the sea side was taken as the standard. The mean reduction factor obtained was 1·50. Since May 1936, the reduction factor was determined by taking observations with an ionium collector connected to a stretched horizontal wire at a height of 1 metre above ground [5] on the neighbouring sea coast, the place of observation being distant about 60 metres from the nearest sea-wall. A Wulf bifilar electrometer was used and the mean reduction factor obtained was 1·92. In this paper, the latter value of the reduction factor has been used to reduce the readings obtained from the electrograms.

A general examination of the daily records of potential gradients obtained in the previous years showed two significantly different types of diurnal variation—one characteristic of the southwest monsoon season, and the other of the dry months. To investigate the cause of this difference, observations of electric conductivity were started in 1935. A Gerdien conductivity apparatus made by Messrs. Spindler & Hoyer and fitted with a Wulf bifilar electrometer was used. Observations of conductivity were taken at the full hours of Local Mean Time. which is 4 h. 51 m. ahead of Greenwich Mean Time. Observations at 10 hrs. were taken almost daily as a routine. For the study of diurnal variation, almost continuous hourly observations on 5 or 6 electrically ' quiet ' days were taken every month during the period July 1935 to August 1936. During the monsoon, however, owing to interruption by frequent showers of rain, strictly continuous hourly observations were not possible except on a few occasions. During this period recourse was had to quasi-continuous measurements, the observational hours being so distributed as to secure data in all the 24 hours. The present paper discusses the results of these hourly observations (each of which consisted of two individual observations of positive and negative conductivity respectively) together with the associated values of potential gradient and air-earth current. About 1,600 hourly observations are available for the analysis of the diurnal variation of conductivity.

The observations of conductivity were made on the third floor of the balloon tower at a height of 14 metres above the adjoining ground and 23 metres above mean sea-level. The observation room is of dimensions 3·3 m. × 3·1 m. and is provided with doors on all sides. Being above the level of the immediately surrounding objects such as trees and other buildings, the room has a very good exposure. The tower is at a distance of about 150 metres from the potential gradient electrograph hut, and it is possible that there is a slight difference between the values of conductivity measured in the two places. Comparative measurements made one after the other at the top and bottom of the tower on electrically ' quiet ' days in July and August showed that there was no appreciable difference between the values of conductivity as measured on the third floor of the tower and near the ground. (During inversion nights there may be some difference, but this requires investigation).

In order to facilitate the measurements of diurnal variation, the hand drive of the conductivity apparatus was replaced by an electric drive. The fan was directly coupled to a small motor of 1/8 H. P. and 220 volts A. C. The motor was placed on the side away from the mouth of the air-funnel and the room was well ventilated so that fresh air was always sucked into the conductivity apparatus. The insulation of the instrument during the monsoon at Bombay presents some difficulty, but it

was satisfactorily overcome by keeping the instrument heated electrically at all times when it was not actually being used for an observation and cleaning the exposed surface of the amber insulator with a piece of silk when necessary. Insulation tests were made almost every time before and after an observation. The leakage of the electrometer was very small being generally between 0·05 to 0·2 divisions of scale in 3 minutes when the fan was not working, as against 5 to 9 divisions in the same interval when air was being sucked in. No correction for leakage has therefore been applied in the values given. Negative and positive conductivity were observed alternately. Two observations of each were generally taken during an hour.

A potential of about ± 80 to ± 100 volts was applied to the inner electrode of the conductivity apparatus and the period of aspiration was 3 minutes. The velocity of aspiration did not differ appreciably from that with the hand drive with 120 to 140 turns of the handle per minute. The observations were reduced by using the usual formula of Gerdien with Swann's correction[6] of 22 per cent for the influence of the supporting rod connecting the inner electrode to the electrometer and the distortion of the field inside the tube at the ends of the inner electrode

Results.

The data discussed in the present paper were selected from the hourly observations of conductivity taken during 'quiet' days on which there were no abnormal weather phenomena such as thunderstorms, heavy showers and the like. The number of observations of conductivity in each hour of the day used for calculating the hourly means is given in *Table 1*. In *Tables 2, 3* (*a* and *b*) and *4* are given the monthly and seasonal mean values of potential gradient (F), total conductivity (λ), positive conductivity ($\lambda+$), and positive air-earth current ($i+$), respectively for each hour of the day. *Table 5* gives a summary of the mean values of the above quantities obtained from the much larger number of observations (given in brackets) taken at 10 hrs. local time. The maxima and minima have been indicated in bold type

In the same *Tables 2, 3(a)* and *5* are also shown in italics the square root of the variance $s=\sqrt{\frac{S(x-\bar{x})^2}{N-1}}$ of the quantities F and λ. Here $S(x-\bar{x})^2$ is the sum of the squares of the deviations from the mean and $N-1$ is the number of observations minus one or the number of degrees of freedom. Those mean values which are less than $2s$ are marked with an asterisk. It will be seen that the fluctuations of F and λ are generally least in the afternoon day hours and greatest near about midnight and within two or three hours after sunrise.

The mean potential gradient during the interval of conductivity observation was read from the traces of the self-recording instrument and corrected by multiplication by the "exposure-factor".

No table has been given for the ratio of the positive to negative conductivity, but it may be mentioned that the mean monthly values of λ_+/λ_- ranged from 0·94 to 1·01, the value during the monsoon months being on the average 1·00 and during the other months 0·97.

Discussion.

As a preliminary to the discussion of the above results, we shall give a brief summary of the normal meteorological features of Bombay which have a bearing on atmospheric electric phenomena.

The most well-marked seasons in Bombay are the winter—November to February, the hot season—March to May, and the monsoon season—June to September. October is a post-monsoon transition month, which for purposes of averaging has been combined with the hot season or pre-monsoon months March to May. The winter days are sunny with generally blue skies and occasional high clouds. Land-breeze in the early hours of the day and sea-breeze in the afternoons are almost daily features. Ground fog is a rare phenomenon near the observatory. A pall of thin haze or mist (occasionally thickening to fog) forms almost every morning over the neighbouring coast. The maximum atmospheric obscurity near the ground level occurs at 8—9 hrs., after which the haze gets lifted by vertical convection. With the onset of the sea-breeze which occurs soon after noon, it rapidly disperses. The afternoon is generally the time of maximum transparency of the atmosphere. On some occasions, when the wind comes from north or north-north-west and its velocity exceeds 8 m/sec. the air becomes visibly charged with dust probably carried from the mill areas in north Bombay. On such occasions, this is observed to cause reversal of the potential gradient.

The months March to May have somewhat similar characteristics as the winter months, the most outstanding difference being that, as the season advances, the sea-breeze becomes stronger and persists for a longer time, while the duration of the land-breeze gets shorter. In April, May and October, afternoon thunderstorms are not unusual. In contrast to the above, the monsoon days are characterised by generally cloudy skies and showers of rain with a fairly steady wind-direction, the air supply over Colaba being directly from over the sea.

Variation of potential gradient, conductivity and air-earth current.

(1) Annual variation.

In *Figs. 1* and *2* are shown the curves of annual variation of the three quantities,—potential gradient, conductivity and air-earth current on electrically 'quiet' days. The mean value of potential gradient is 150 volts/metre, of conductivity $2 \cdot 5 \times 10^{-4}$ E. S. U. and of air-earth current $5 \cdot 9 \times 10^{-7}$ E. S. U. or $2 \cdot 0 \times 10^{-16}$ amp. cm. $^{-2}$ sec. $^{-1}$. The climatic phenomena of Bombay are sufficiently regular for the means based on even so few observations as those considered in the present paper to give a reliable idea of the general variations during the year. The air-earth currents have been calculated by multiplying the potential gradient at each hour by the corresponding positive conductivity [9]. Two sets of curves have been drawn, one based on all observations taken on days of whole day observations (*Fig. 1*) and the other based on the much larger number of 10 hrs. observations alone (*Fig. 2*). Both sets of curves show that—

(*i*) the mean potential gradient is a maximum in mid-winter, December—January, and minimum in May. The 10 hrs. observations show a secondary minimum in August—September.

(*ii*) the variation of conductivity is roughly but not exactly inverse to that of potential gradient [4]. It increases rapidly from February to April and decreases as rapidly from September to November.

(*iii*) the air-earth current is highest in the monsoon months and least in the months March to May.

It is easy to understand why, during winter, the mean value of the conductivity should be small. Owing to the stability of the atmosphere and the character of the air movement, the air near the ground collects an appreciable quantity of smoke and nuclei during certain parts of the day reducing the number and mobility of the ions. In the period May to September, owing to the strength and gustiness of the

winds and the fact that the air flow is mainly from the north-west, west or south-west, *i.e.*, from the sea, the conductivity shows high values. A very interesting feature is the increase of air-earth current with the onset of the monsoon. As is clear from *Figs. 1* and *2*, this is due to the marked increase in potential gradient from May to June.

(2) Daily variation.

The diurnal variation of the three electrical elements shown in *Figs. 3, a* to *h*, is simplest during the monsoon (*Fig. 3h.*), when the general wind has only a very small diurnal variation. In this season, the potential gradient has a maximum at about midnight (which corresponds to the time of maximum potential gradient over the oceans—19 hrs. G. M. T.)[3] and a feeble minimum in the afternoon In October (*Fig. 3d.*) there are two maxima during the day in the potential gradient, the main one being near midnight, and the other being between 7 and 12 hrs. in the morning. The forenoon maximum becomes more pronounced with the progress of winter, the two maxima being of nearly the same intensity in January (*Fig. 3a.*). In the hot season months, March and April (*Fig. 3b.*), with the increasing strength and duration of the afternoon sea-breeze, the night maximum dwindles in importance and the forenoon maximum becomes more prominent In the non-monsoon months, the daily variation of conductivity is roughly inverse to that of potential gradient so that the air-earth current shows less variation than either potential gradient or conductivity, the only definite variation being smaller values during the day and a maximum within a couple of hours of local midnight coinciding with the maximum over the ocean.[3]

Except in the winter, the conductivity and air-earth current are generally higher during the night hours than during day. Conspicuous minima of these quantities occur at about the times of sunrise and sunset. While there is little doubt that the secondary maximum of conductivity in the afternoon hours is due to convective mixing of the air near the ground with the purer upper atmosphere and the dispersion of pollution by wind, the generally smaller values at about the time of sunrise are perhaps to be ascribed to some deleterious influence of solar radiation on either the number or the mobility of the ions due to changes in the number or nature of nuclei. It may be remembered that while the average conductivity over the ocean is greater during the day than during the night, observations at a high level station like Davos[2] in Switzerland show a somewhat similar behaviour to that observed at Bombay in monsoon with marked decrease of conductivity during the day-hours. The reason for these differences is not clear. It is likely that data on nuclei variation will throw light on this point.

In order to show how the afternoon maximum of conductivity is related to wind, curves of mean wind speed and direction and conductivity in the three months January, April and July are drawn in *Fig. 4, a* to *c*. The wind data used refer only to the hours on which conductivity observations were taken. They show that between 10 and 18 hrs. the two curves are nearly parallel.

Comparison of daily variation of potential gradient at Bombay with that over the oceans.

From the potential gradient observations taken on board the *Carnegie*, Mauchly[3] discovered that over the oceans, the daily variation of potential gradient is very simple in character depending not on local time but on universal time—the maximum value of potential gradient being at 18 to 19 hrs. G. M. T. and the minimum at about 4 hrs. G. M. T. As mentioned already, the air over Colaba in the monsoon comes directly from the sea and hence it may be expected that the diurnal variation in this season will approach that over the ocean. *Fig. 5* compares the diurnal variation

of potential gradient over Bombay in the monsoon (June-September) and the winter seasons (November-February) with that over the ocean. The parallelism of the former with the ocean variation between 10 and 19 hrs. is clear. Even in winter, the trend of variation is similar, but the disturbance due to local effects is much too large for the similarity to be conspicuous.

Some specific examples of changes in potential gradient and conductivity with change in wind-direction.

The daily alternating changes of wind-direction which is a very marked feature of Bombay weather in all non-monsoon months generally cause large and abrupt changes of potential gradient. These are also accompanied by corresponding changes of conductivity. Four examples in different months of the year are briefly discussed below.

Example 1.—5th to 6th November, 1935 (*Fig. 7*).*

The wind was north-westerly and from the sea in the afternoon hours of the 5th. The direction changed to north-east at about 22·30 hrs. and later to easterly. This land wind persisted till 10·30 hrs. on the 6th when it again changed to north-westerly. The sea winds were as usual more gusty. The larger values of potential gradient during the period of land-winds with conspicuous maxima during the first two or three hours after their commencement and before their cessation are well shown in the figure. There were only three measurements of conductivity during the land wind hours, but they all show the decreased conductivity of the easterly air as compared with that of the sea air. The maxima of potential gradient occur apparently when the atmospheric pollution[1] over the observatory reaches a maximum. This occurs (*i*) when the smoke haze from the mill area in north Bombay (about 10 kms. north of the observatory) which had been heaped up against the coastal hills on the eastern side of the Bay extending north and south by the north-westerly sea winds is brought by the returning land-winds over the observatory, (*ii*) when the morning sunshine sets up turbulence in the lower atmosphere, mixes up the haze layer near the ground and the winds bring up some of it and smoke from the city over the observatory.

It is assumed that the changes of potential gradient, and more so of conductivity, are almost entirely due to changes in smoke[10] and the nuclei[7] content of the air.

Example 2.—April 28th, 1936. (*Fig 6*).

The changes are similar, but the duration of easterly wind and the corresponding variations in potential gradient and conductivity extend only over a period of 5 to 6 hrs. on the morning.

Example 3.—28th July, 1936. (*Fig. 8*).

This was a typical monsoon day with continuous air supply from the sea. Both the potential gradient and the wind curves show very little diurnal variation and the former is conspicuous by the absence of high values which mark the curves of the preceding two seasons. The conductivity bears no marked correspondence with potential gradient and is of the usual monsoon type with low values at about sunrise and sunset and higher values at night.

*The values of conductivity shown in *Figs. 6* to *9* are to be multiplied by 0·82 to get the absolute magnitude.

Example 4.—16th September, 1936. (*Fig. 9*).

This chart illustrates the effect of land-wind but without mixture of additional pollution from the city area. The wind suddenly veered from WSW through S to E at about 4·20 A.M. and after a few minutes duration changed to SE and remained there till about 9 A.M. Thereafter it again changed direction blowing between S and W. The first change to east was accompanied by a corresponding rise in potential gradient. As might be expected the potential gradient was generally higher during the prevalence of the southeasterly wind than when it was from the west or south-west. A fall in conductivity is noticed corresponding to the rise of potential gradient, otherwise it shows the usual monsoon variation.

The conductivity observations were first started under Dr. S. C. Roy, M.Sc., D.Sc. (Lond.). Both to him and to Dr. K. R. Ramanathan, M.A., D.Sc., who has taken very keen interest in the work ever since he assumed charge of this observatory and helped me in various ways, I tender my grateful thanks. My thanks are also due to Mr. A. S. Chaubal, B.Sc., who assisted me in taking a few observations during monsoon.

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TABLE 1.—*Number of Observations of Total Conductivity.*

Year and Month. (Hrs. L. M. T.)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Sum.
1935—																									
July	4	1	.	5	.		4		4		3	..	4	4	6		6	4	6	2	4	4	5	.	66
August	7	2	3	4	2	2	7	4	5	5	4	4	5	6	10	7	10	7	7	5	6	4	6	4	126
September	5	5	5	7	5	3	7	6	6	2	6	5	6	7	6	5	6	6	6	5	6	4	8	5	132
October	3	3	4	5	6	4	10	7	7	4	7	2	2	8	9	6	6	3	6	6	7	4	4	4	127
November	5	5	6	7	7	5	7	5	8	4	7	7	10	7	7	9	6	6	7	6	5	6	6	5	153
December	5	3	4	7	6	6	8	7	7	7	6	4	3	6	5	5	6	4	4	4	6	4	5	4	126
1936—																									
January	4	5	5	4	5	5	4	7	7	7	5	5	6	5	6	6	7	5	5	5	4	4	5	5	126
February	6	6	6	6	6	5	6	6	6	6	6	3	5	5	6	7	7	5	6	4	5	6	5	5	134
March	3	4	4	4	4	4	5	4	5	5	4	4	4	6	5	5	6	3	4	5	3	3	4	4	102
April	3	4	5	5	5	4	5	5	5	5	5	5	5	4	5	5	5	5	5	5	5	4	5	4	113
May	4	4	5	6	5	5	7	6	6	6	6	6	6	6	7	6	6	6	6	6	5	5	5	4	134
June	5	4	4	4	4	4	9	8	7	7	5	7	6	6	7	6	4	3	4	5	5	5	6	4	129
July	3	5	5	5	5	4	7	6	6	7	4	7	5	4	5	6	5	5	4	5	6	7	5	4	125
August	..	1	1	1	1	1	1	1		1	1	2	1	4	3	2	..	..	..	..	.	..	2	2	25
Sum.	57	52	57	70	61	52	87	72	79	66	69	61	68	78	87	75	80	62	70	63	67	60	71	54	1,618

TABLE 2.—*Potential*

Hrs. (L. M. T.) / Month or Season.	0	1	2	3	4	5	6	7	8	9	10	11
January	282 ±*58*	205 ±*62*	232 ±*47*	228 ±*60*	204 ±*20*	239 ±*43*	229 ±*64*	236 ±*95*	286 ±*59*	276 ±*76*	244 ±*110*	135 ±*31*
February	214 ±*96*	210* ±*148*	189 ±*78*	174 ±*74*	206 ±*48*	243 ±*54*	238 ±*58*	235 ±*71*	280 ±*63*	255 ±*44*	205 ±*73*	191 ±*59*
March	81* ±*57*	57* ±*31*	114* ±*107*	112 ±*46*	164 ±*65*	144 ±*49*	188* ±*98*	177 ±*63*	181* ±*134*	172* ±*168*	128 ±*50*	133 ±*61*
April	101* ±*92*	118 ±*50*	109 ±*33*	87* ±*49*	120* ±*79*	159 ±*35*	214 ±*61*	227* ±*118*	243 ±*115*	113 ±*41*	93 ±*33*	93 ±*19*
May	98 ±*7*	88 ±*3*	84 ±*22*	72 ±*33*	71 ±*25*	81 ±*20*	110 ±*24*	111* ±*58*	94 ±*25*	101 ±*28*	110 ±*28*	103 ±*17*
June	146 ±*24*	147 ±*26*	147 ±*8*	151 ±*5*	137 ±*8*	146 ±*12*	129 ±*33*	128 ±*26*	131 ±*33*	138 ±*31*	156 ±*38*	143 ±*46*
July	162 ±*28*	158 ±*23*	166 ±*34*	166 ±*29*	152 ±*26*	165 ±*26*	178 ±*21*	155 ±*22*	156 ±*21*	155 ±*19*	155 ±*15*	134 ±*30*
August .. .	170 ±*27*	159 ±*23*	140 ±*20*	147 ±*45*	156 ±*37*	146 ±*26*	143 ±*38*	144 ±*32*	154 ±*29*	142 ± *40*	139 ±*34*	142 ±*42*
September	181 ±*40*	202 ±*47*	183 ±*51*	183 ±*39*	183 ± *40*	179 ±*51*	164 ±*44*	157 ±*8*	157 ±*43*	157 ±*19*	140 ±*24*	143 ±*18*
October	290 ±*107*	224 ±*70*	203 ±*33*	173 ±*21*	123 ±*48*	127 ±*39*	154 ±*74*	171* ±*92*	164 ±*52*	154 ±*26*	159 ±*33*	167 ±*14*
November .. .	174 ±*56*	177 ±*63*	161 ±*47*	169 ±*70*	154 ±*31*	151 ±*41*	165* ±*90*	131 ±*36*	157 ±*44*	204 ±*53*	165 ±*36*	156 ±*36*
December	268 ±*79*	240 ±*69*	234 ±*45*	205 ±*37*	156 ±*46*	203 ±*52*	206 ±*75*	231 ±*98*	223 ±*81*	251 ±*99*	193 ±*33*	213 ±*13*
Year	181	165	163	156	152	165	176	175	185	176	157	146
Winter or Dry	235	208	204	194	180	209	209	208	237	247	202	174
Pre. and Post- Monsoon or Hot.	143	122	127	111	119	128	167	171	171	135	123	124
Monsoon or Wet ..	165	167	159	162	157	159	152	146	149	148	147	141

*The hourly means whose standard deviations $\sqrt{S(x-\bar{x})^2/(N-1)}$

Gradient in volts/metre—Monthly Means.

12	13	14	15	16	17	18	19	20	21	22	23	Daily Mean.
117 ±*38*	108 ±*24*	115 ±*40*	98 ±*30*	111 ±*34*	112 ±*24*	127 ±*24*	146 ±*29*	169 ±*23*	183 ±*67*	198 ±*97*	266* ±*243*	189
140 ±*48*	96 ±*34*	95 ±*24*	114* ±*59*	133* ±*81*	141* ±*84*	129 ±*48*	133 ±*46*	124 ±*44*	128* ±*70*	103 ±*42*	124 ±*41*	173
71 ±*32*	90 ±*27*	76 ±*23*	94 ±*5*	79 ±*28*	71 ±*12*	110 ±*49*	142 ±*48*	115 ±*22*	124 ±*55*	146* ±*86*	89* ±*49*	121
91 ±*24*	91 ±*33*	77 ±*24*	77 ±*19*	69 ±*19*	74 ±*12*	90 ±*14*	95 ±*17*	99 ±*19*	100 ±*24*	92 ±*14*	86 ±*13*	115
102 ±*13*	98 ±*17*	100 ±*10*	103 ±*20*	97 ±*18*	97 ±*16*	109 ±*14*	114 ±*20*	122 ±*16*	114 ±*10*	97 ±*18*	98 ±*20*	97
141 ±*24*	133 ±*18*	120 ±*22*	116 ±*18*	116 ±*15*	132 ±*8*	129 ±*15*	128 ±*17*	141 ±*22*	147 ±*14*	157 ±*22*	155 ±*19*	138
149 ±*23*	147 ±*27*	140 ±*27*	132 ±*19*	129 ±*20*	137 ±*20*	141 ±*29*	145 ±*23*	142 ±*21*	144 ±*24*	141 ±*23*	150 ±*21*	150
154 ±*23*	150 ±*26*	142 ±*30*	135 ±*31*	136 ±*20*	138 ±*31*	136 ±*22*	142 ±*25*	152 ±*54*	161 ±*62*	159 ±*43*	161 ±*26*	148
146 ±*32*	133 ±*13*	136 ±*44*	135 ±*17*	131 ±*51*	146 ±*22*	147 ±*14*	154 ±*10*	147 ±*14*	149 ±*14*	147 ±*13*	135 ±*15*	155
172 ±*21*	146* ±*79*	114 ±*36*	109 ±*23*	108 ±*14*	119 ±*6*	122 ±*26*	143 ±*53*	130 ±*47*	132 ±*37*	181 ±*52*	230* ±*129*	159
174 ±*55*	105 ±*43*	103* ±*55*	96 ±*23*	119 ±*24*	127 ±*33*	155 ±*45*	153 ±*36*	161 ±*26*	193 ±*51*	237 ±*107*	285 ±*73*	162
167 ±*67*	142 ±*55*	126 ±*63*	117 ±*36*	126 ±*31*	143 ±*36*	163 ±*35*	176 ±*51*	171 ±*43*	199 ±*83*	301 ±*102*	302 ±*75*	198
135	120	112	110	113	120	130	139	140	148	163	173	150
149	113	110	106	122	131	143	152	156	176	210	244	180
109	106	92	96	88	90	108	123	117	117	129	126	123
147	141	135	127	128	138	138	142	148	150	151	150	147

exceed 50 per cent of the means are marked with an asterisk.

TABLE 3 (*a*).—*Total Conductivity*

Month or Season. \ Hrs. (L. M. T.)	0	1	2	3	4	5	6	7	8	9	10	11
January .. .	1·25 ±0·20	1·54 ±0·50	1·37 ±0·59	1·57 ±0·50	1·13 ±0·39	0·97 ±0·45	1·13 ±0·52	0·87* ±0·59	1·21 ±0·57	1·25 ±0·35	1·32 ±0·21	2·12 ±0·57
February	1·86* ±1·50	1·86* ±1·25	1·86* ±1·14	2·04* ±1·31	1·31 ±0·23	1·07 ±0·42	0·84* ±0·65	0·93* ±0·55	1·08* ±0·65	1·23 ±0·55	1·53 ±0·67	1·65* ±0·83
March ..	3·27 ±0·39	3·09 ±0·28	3·03 ±1·40	2·89 ±1·35	1·94* ±1·12	1·10 ±0·39	0·98* ±0·92	1·29* ±0·75	1·57 ±0·75	1·97* ±1·06	1·81* ±0·98	2·07 ±0·74
April	3·73 ±0·72	3·17 ±1·26	2·85* ±1·60	3·28 ±1·37	2·45* ±1·48	1·13* ±0·66	0·74* ±0·52	1·01* ±0·75	1·12* ±0·92	2·16* ±1·44	2·66 ±0·36	3·03 ±0·41
May ..	3·30 ±0·59	3·37 ±0·34	3·51 ±0·39	3·58 ±0·84	3·21 ±0·22	2·35 ±0·99	1·57 ±0·74	2·21 ±0·88	2·44 ±0·46	2·28 ±0·62	2·62 ±0·48	2·80 ±0·07
June	3·38 ±0·59	3·53 ±0·61	3·54 ±0·66	3·35 ±0·61	3·26 ±0·89	2·81 ±0·85	2·29 ±0·70	2·80 ±0·71	2·84 ±0·54	2·78 ±0·38	2·77 ±0·27	3·00 ±0·37
July	3·72 ±0·37	3·39 ±0·45	3·33 ±0·49	3·86 ±0·53	3·30 ±0·36	3·00 ±0·34	2·10 ±0·31	2·42 ±0·47	2·59 ±0·42	2·62 ±0·34	2·49 ±0·42	2·53 ±0·24
August .. .	3·82 ±0·42	3·54 ±0·49	3·33 ±0·14	3·85 ±0·59	3·31 ±0·84	2·76 ±0·43	2·04 ±0·45	2·00 ±0·37	2·67 ±0·44	2·84 ±0·34	2·89 ±0·43	2·77 ±0·40
September .. .	3·70 ±0·92	3·02 ±1·07	3·35 ±1·16	3·31 ±1·07	2·82 ±1·22	2·48 ±0·64	1·80 ±0·58	2·31 ±0·56	2·53 ±0·39	2·85 ±0·71	2·71 ±0·46	3·07 ±0·66
October	2·18 ±0·48	2·09 ±0·79	2·35 ±0·78	2·18 ±1·01	2·84 ±0·39	2·46 ±0·41	1·57 ±0·66	1·76* ±0·94	1·83 ±0·60	1·93 ±0·26	1·94 ±0·29	2·52 ±0·25
November .. .	1·98 ±0·84	2·11 ±0·76	2·31 ±0·43	2·36 ±0·44	2·23 ±0·71	2·18 ±0·59	1·66 ±0·81	1·91 ±0·40	1·85 ±0·11	1·73 ±0·14	1·79 ±0·28	2·00 ±0·53
December	1·80 ±0·55	1·37 ±0·36	1·51 ±0·49	1·52 ±0·54	1·89 ±0·92	1·44* ±0·73	1·42 ±0·71	1·17 ±0·49	1·58 ±0·46	1·53 ±0·20	1·76 ±0·20	1·77 ±0·07
Year	2·84	2·67	2·70	2·83	2·48	2·02	1·51	1·72	1·94	2·09	2·19	2·44
Winter or Dry ..	1·72	1·72	1·76	1·88	1·64	1·42	1·30	1·22	1·43	1·43	1·60	1·89
Pre- and Post- Monsoon or Hot.	3·12	2·93	2·94	2·98	2·61	1·76	1·21	1·57	1·74	2·08	2·26	2·61
Monsoon or Wet ..	3·66	3·37	3·39	3·59	3·17	2·76	2·06	2·39	2·66	2·77	2·71	2·85

*The hourly means whose standard deviations $\sqrt{S(x-\bar{x})^2/(N-1}$

(Unit= 10^{-4} E. S. U.)—Monthly Means.

12	13	14	15	16	17	18	19	20	21	22	23	Daily Mean.
2·28 ±0 60	2 62 ±0 33	2 74 ±0 59	3 03 ±0 59	2 89 ±0 82	2 71 ±0 51	2 52 ±0 45	2 35 ± 0 77	2 13 ±0 84	2 36 ±0 96	2·06* ±1 24	2 07* ±1 50	1 90
2 07 ±0 71	2 96 ±0 57	3 07 ±0 55	2 97 ±0 71	2 77 ±0 77	2 50 ±0 55	2 39 ±0 54	2 12 ±0 58	2 72 ±0 57	2 94 ±0 86	3 09 ±1 15	2·59* ±1 33	2 06
2 75 ±0 50	2 66 ±0 54	2 80 ±0·60	2 71 ±0 57	2 88 ±0 61	2 83 ±0 48	2 85 ±0 66	2 08 ±0 89	2 82 ±0 38	2 20 ±0 71	2 30 ±0 77	2 68 ±0 53	2·35
2 87 ±0 55	2 98 ±0 46	3 30 ±0 56	3 47 ±0 41	3 41 ±0 50	3 52 ±0 33	3 03 ±0 41	3 06 ±0 82	3 11 ±0 75	3 52 ±0 45	3 97 ±0 44	4·03 ±0 11	2·81
2 90 ±0 18	2 97 ±0 32	2 78 ±0 19	2 71 ±0 25	2 76 ±0 17	2 61 ±0 22	2 50 ±0 13	2 25 ±0 71	2 55 ±0 72	2 92 ±0 29	3 17 ±0 14	3 56 ±0 11	2·79
3 18 ±0 60	3 39 ±0 55	3 50 ±0 57	3 33 ±0 39	3 01 ±0 66	3 01 ±0 76	2 74 ±0 61	2 35 ±0 66	3 13 ±0 67	3 46 ±0 36	3 50 ±0 79	4 16 ±0 88	3·13
2 71 ±0 30	2 86 ±0 43	2 97 ±0 58	2 74 ±0 23	2 62 ±0 26	2 59 ±0 29	2 48 ±0 33	2 46 ±0 45	2 64 ±0 11	3 12 ±0 41	3 51 ±0 43	3 89 ±0 78	2·92
3 10 ±0 59	3 23 ±0 57	3 23 ±0 61	3 15 ±0 50	3 14 ±0 38	3 05 ±0 30	2 97 ±0 43	3 35 ±0 64	3 30 ±1 04	3 88 ±1 02	3 71 ±0 95	3 63 ±1 38	3·15
3 17 ±0 20	3 47 ±0 31	3 17 ±0 51	3 50 ±0 30	3 31 ±0 53	3 26 ±0 12	2 94 ±0 43	2 64 ±0 52	2 87 ±0 59	3 39 ±0 31	3 67 ±0 37	3 99 ± 0·32	3 06
2 77 ±0 30	2 71 ±0 86	2·94 ±0 79	3 10 ±0 39	3 35 ±0 35	2 94 ±0 35	2 71 ±0 26	2 39 ±0 80	2 83 ±0 79	3 16 ±0 95	2 60 ±0 99	2 80 ±1 22	2 51
2 05 ±0 80	2 53 ±0 93	2 63 ±0 86	2 70 ±0 39	2 74 ±0 55	2 58 ±0 40	2 03 ±0 53	2 16 ±0 38	20 1 ±0 66	2 11* ±1 19	1 81* ±1 22	1·59 ±0 45	2·12
1 86 ±0 30	2 29 ±0 48	2 99 ±0 15	3 07 ±0 69	2 93 ±0 85	2 65 ±0 97	2 21 ± 0 80	1 89 ±0 30	2 24 ±0 85	2 35 ±0 20	1 55* ±1 29	1·06* ±1·16	1·90
2·64	2·89	3·01	3 03	2 98	2·85	2 62	2 43	2 70	2 95	2 92	3 00	2 56
2 07	2 59	2 85	2 94	2 83	2 62	2 30	2 13	2 28·	2 44	2 13	1·82	2·00
2·82	2·83	2·95	3 00	3 10	2 98	2 77	2 44	2 83	2 95	3·01	3·26	2·62
3 04	3 24	3·22	3 17	3 02	2·98	2·79	2 70	2 98	3 46	3 60	3·92	3 05

exceed 50 per cent of the means are marked with an asterisk.

TABLE 3 (*b*).—*Positive Conductivity*

Month or Season. \ Hrs. (L. M. T.)	0	1	2	3	4	5	6	7	8	9	10	11
January ..	0·60	0·75	0·67	0·76	0·54	0·47	0·58	0·43	0·62	0·63	0·64	1·04
February ..	0·89	0·89	0·89	1·00	0·63	0·53	0·40	0·48	0·56	0·61	0·71	0·82
March ..	1·62	1·51	1·46	1·39	0·89	0·52	0·47	0·66	0·78	0·97	0·89	1·01
April .	1·82	1·57	1·41	1·64	1·19	0·55	0·35	0·50	0·57	1·06	1·29	1·48
May .. .	1·65	1·66	1·72	1·71	1·57	1·18	0·80	1·07	1·20	1·12	1·28	1·41
June	1·73	1·80	1·82	1·72	1·62	1·46	1·12	1·43	1·44	1·39	1·43	152
July	1·87	1·75	1·71	1·94	1·67	1·53	1·04	1·19	1·30	1·33	1·25	1·27
August	1·90	1·79	1·65	1·90	1·66	1·30	0·94	0·98	1·30	1·39	1·43	1·40
September .	1·85	1·51	1·70	1·69	1·40	1·21	0·90	1·17	1·25	1·45	1·34	1·54
October	1·07	1·15	1·16	1·11	1·36	1·18	0·77	0·89	0·92	0·97	0·96	1·24
November	0·98	1·06	1·16	1·16	1·10	1·09	0·83	0·93	0·92	0·88	0·88	1·01
December	0·92	0·70	0·75	0·75	0·96	0·72	0·71	0·58	0·80	0·75	0·89	0·86
Year	1·41	1·34	1·34	1·41	1·22	1·02	0·75	0·86	0·97	1·04	1·08	1·21
Winter or Dry ..	0·84	0·84	0·87	0·92	0·81	0·71	0·63	0·61	0·72	0·71	0·78	0·93
Pre- and Post-Monsoon or Hot.	1·54	1·44	1·43	1·46	1·25	0·86	0·60	0·78	0·86	1·03	1·11	1·29
Monsoon or Wet ..	1·84	1·71	1·72	1·81	1·59	1·37	1·00	1·20	1·32	1·39	1·36	1·43

(Unit = 10^{-4} E. S. U.)—Monthly Means.

12	13	14	15	16	17	18	19	20	21	22	23	Daily Mean.
1 12	1 28	1·34	1·48	1 39	1 34	1 22	1·19	1 04	1 17	1·03	1·00	0·93
1·02	1 42	1·47	1 45	1 33	1 22	1 17	1·03	1 34	1 42	1 52	1·25	1·00
1 29	1 27	1 34	1 31	1 38	1 34	1 36	1·03	1 37	1·07	1 09	1 33	1·14
1·36	1 44	1 56	1 67	1 67	1 72	1 47	1 48	1 57	1 71	1·98	1 98	1·38
1 40	1 43	1 36	1 34	1 36	1 26	1 22	1 12	1 30	1 46	1·56	1·75	1·37
1 59	1·70	1 73	1 66	1 48	1 48	1 39	1 18	1·51	1·73	1·75	2·01	1·57
1 37	1 43	1 48	1 36	1·32	1 30	1 22	1 21	1·32	1 57	1 77	1·94	1·47
1 60	1 58	1 60	1 52	1 55	1 51	1 46	1 59	1 63	1·86	1 81	1·79	1·54
1·57	1 69	1 55	1 70	1 65	1 62	1 47	1 33	1·43	1·69	1 85	2·00	1·53
1·37	1·27	1 43	1 53	1 66	1·47	1 35	1·20	1 40	1·57	1 29	1·38	1·24
1·02	1·21	1 29	1·32	1 34	1 25	1·00	1·11	1 96	0·99	0·89	0·82	1·05
0·91	1·13	1·46	1·49	1·40	1·31	1·08	0 97	1·13	1·14	0·76	0·52	0·94
1·30	1·40	1·47	1·48	1·46	1·40	1·20	1 21	1·34	1 45	1·45	1·48	1·26
1·02	1·25	1·39	1·43	1·36	1·29	1 12	1·07	1·12	1·18	1·05	0·89	0·98
1·35	1·35	1·42	1·47	1·52	1·45	1·35	1·21	1·41	1·45	1·48	1·61	1·28
1·53	1·60	1·59	1·56	1·50	1·48	1·39	1·33	1·47	1·71	1·80	1·94	1·53

TABLE 4 —*Air-Earth Current*

Hrs. (L. M. T.) / Month or Season.	0	1	2	3	4	5	6	7	8	9	10	11
January ..	5·7	5 1	5·2	5 8	3 7	3 7	4 4	3 4	6 0	5 8	5 2	4·7
February	6·3	6 1	5 5	5·8	4·3	4 3	3 1	3 7	5 2	5 2	4 8	5 2
March	4·3	2·9	5 5	5 2	4 8	2 5	3 0	3 9	4 7	5 5	3 9	4 4
April ..	6·1	6 2	5 2	4 8	4 8	3 0	2 5	3 8	4 6	4 0	4 0	4 6
May	5 3	4 8	4 8	4 1	3 8	3 2	2 9	3 9	3 8	3 8	4 7	4 8
June . ..	8·4	8 9	8·9	8 7	7 5	7 1	4 8	6 1	6 3	6·4	7·5	7·2
July	10 1	9 2	9 5	10 7	8·4	8 4	6 0	6 1	6 7	6 9	6·5	5·7
August ..	10 7	9 5	7 7	9 3	8·7	6 3	4 5	4 8	6 6	6 6	6 6	7 3
September .	11 1	10 2	10 3	10 3	8·5	7 2	4 9	6 1	6 5	7 6	6 2	7·4
October .	10·4	7 9	7 9	6 3	5 6	4 9	3·9	5·2	5·0	4·9	5 1	6·9
November ..	5 7	6 2	6 2	6 6	5·7	5 7	4 5	4 1	4·8	6 0	4 8	5·2
December ..	8 2	5 6	5 8	5 1	5 0	4 8	4 8	4 5	5 8	6 2	5 7	6·1
Year	7·7	6·9	6·9	6·9	5·9	5·1	4·1	4·7	5·5	5 7	5 4	5 8
Winter or Dry ..	6 5	5·7	5·7	5 8	4·7	4 7	4 2	3 9	5 5	5·8	5·2	5·3
Pre- and Post- Monsoon or Hot.	6·6	5·5	5·8	5·1	4·8	3·4	3·0	4·2	4·5	4·5	4·4	5·2
Monsoon or Wet ..	10·1	9 4	9 1	9·8	8·3	7·3	5·1	5·8	6·6	6·8	6·7	6 9

(*Unit*=$^{-7}$ *E. S. U.*).

12	13	14	15	16	17	18	19	20	21	22	23	Daily Mean.
4·3	4·7	5·1	4·8	5·2	5·1	5·2	5 8	5·9	7·1	6·7	8·9	5·2
4·8	4·5	4·7	5 5	6·0	5·7	5·1	4·5	5·5	6·1	5·2	5·2	5·1
3 0	3 8	3·4	4·1	3·6	3·3	5·0	4·8	5·3	4·4	5·3	3·9	4·1
4·1	4·3	4·0	4·3	3·9	4 3	4·4	4·6	5·2	5·7	6·1	5·7	4·6
4·8	4·6	4·5	4·6	4·4	4 1	4·4	4·2	4·2	5·6	5·1	5·7	4·4
7 5	7·5	6·9	6 5	5·7	6·5	6 0	5·0	7·1	8·5	9·1	10·4	7·2
6·8	6·9	6·9	6·0	5 7	6·0	5·7	5·9	6·2	7·5	8·4	9·8	7·4
8·2	8 0	7·5	6·8	7·1	7·0	6 6	7·5	8·3	10·0	9·6	9·6	7·7
7 6	7·5	7·1	7·1	7·2	7·9	7 2	6·8	7·0	8·3	9·0	9·0	7·9
7·9	6·1	5 4	5·6	6 1	5·8	5·4	5·7	6·1	6·9	7·8	10·6	6·3
5·8	4·2	4·4	4·2	5·3	5·3	5·2	5·7	5·2	6·3	7·0	7·8	5·5
5·1	5·3	6·1	5·7	5·8	6·2	5·8	5·7	6·5	7·5	7·6	5·2	5·8
5·8	5·7	5·5	5·4	5·4	5·6	5·5	5·5	6·1	7·0	7·2	7·6	5·9
5·0	4·7	5·1	5·1	5·6	5·6	5·3	5·4	5·7	6·8	6·6	6·8	5·4
4·9	4·7	4·3	4·7	4·4	4·3	4·8	4·8	5·2	5·7	6·1	6·5	4·8
7·5	7·5	7·1	6·6	6·4	6·8	6·4	6·3	7·2	8·6	9·0	9·7	7·5

TABLE 5.—*Mean Values of Electric Elements at 10 hrs.*

Element. \ Month or Season.	Jan.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep.	Oct	Nov	Dec	Year	Winter	Pre- and Post-Monsoon	Mon-soon.
F (v/m)	(18) 246 ±*75*	(18) 226 ±*51*	(16) 141 ±*44*	(21) 110* ±*56*	(16) 97 ±*22*	(25) 154 ±*41*	(31) 159 ±*31*	(18) 143 ±*25*	(15) 139 ±*21*	(17) 167 ±*43*	(22) 183 ±*43*	(14) 194 ±*46*	(231) 163	(89) 212	(70) 129	(72) 149
$\lambda \times 10^4$ E.S.U.) ..	1·32 ±*0·34*	1·49 ±*0·53*	1·67 ±*0·72*	2·57 ±*0·57*	2·65 ±*0·25*	2·62 ±*0·59*	2·44 ±*0·35*	2·71 ±*0·44*	2·80 ±*0·57*	1·98 ±*0·43*	1·71 ±*0·30*	1·70 ±*0·27*	2·13	1·53	2·21	2·64
$\lambda_+ (\times 10^4$ E.S.U.) ..	0·66	0·73	0·82	1·25	1·31	1·32	1·21	1·34	1·39	0·98	0·84	0·84	1·06	0·76	1·09	1·32
$i_+ (\times 10^7$ E.S.U.) ..	5·4	5·5	3·9	4·6	4·3	6·8	6·4	6·4	6·4	5·5	5·1	5·5	5·5	5·3	4·5	6·5

*The hourly means whose standard deviations $\sqrt{S(x-\bar{x})^2/(N-1)}$ exceed 50 per cent of the means are marked by an asterisk. This large deviation is due to a single observation. If that is rejected, the deviation is $\pm 38 v/m$ and the mean value is 98 v/m

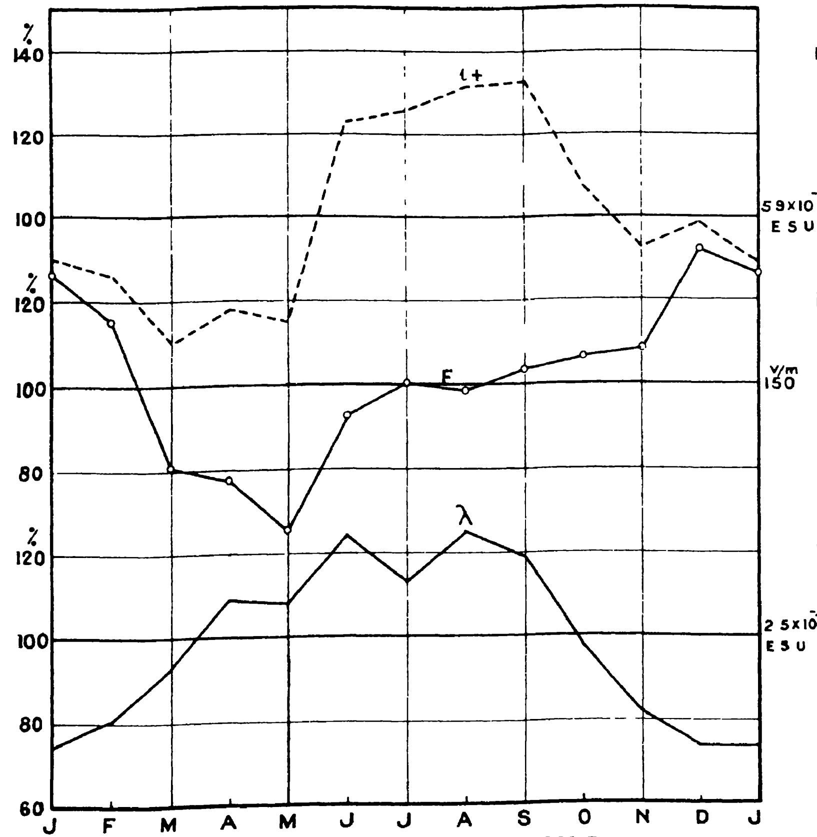

FIG 1 QUIET DAYS, ALL HOURS.

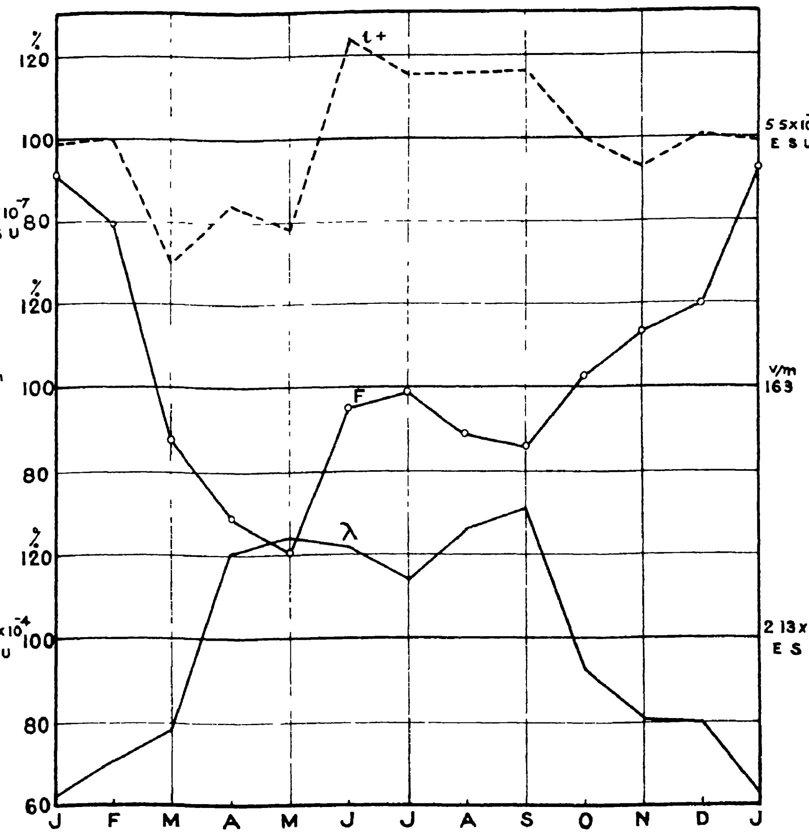

FIG. 2. ALL DAYS, 10 Hrs

ANNUAL VARIATIONS OF CONDUCTIVITY, POTENTIAL GRADIENT AND AIR-EARTH CURRENT AT COLABA.

G P Z O POONA, 1938

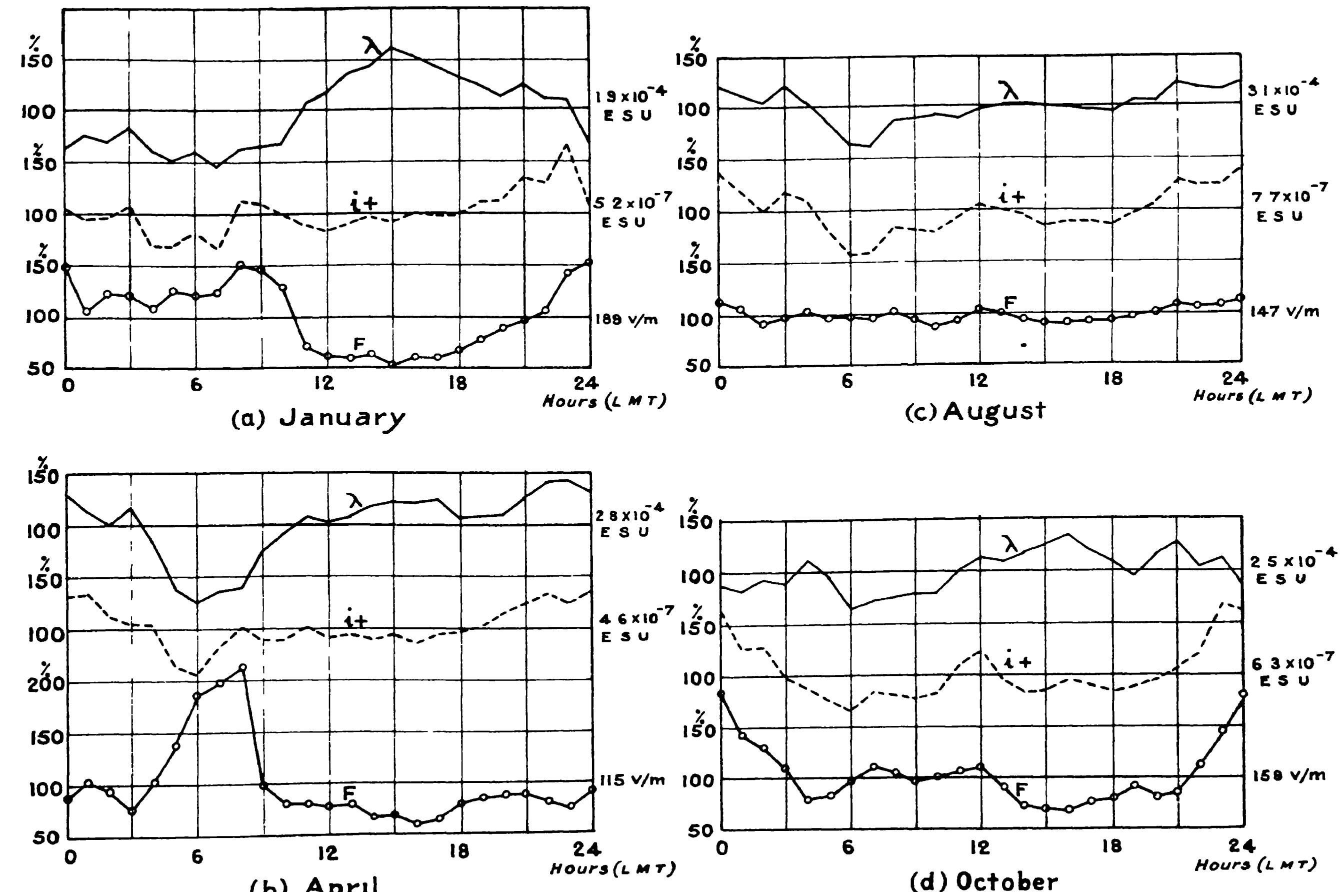

FIG. 3a. DIURNAL VARIATION OF POTENTIAL GRADIENT, CONDUCTIVITY AND AIR-EARTH CURRENT AT COLABA ON ELECTRICALLY QUIET DAYS (1935-36)

G P Z O POONA, 1938

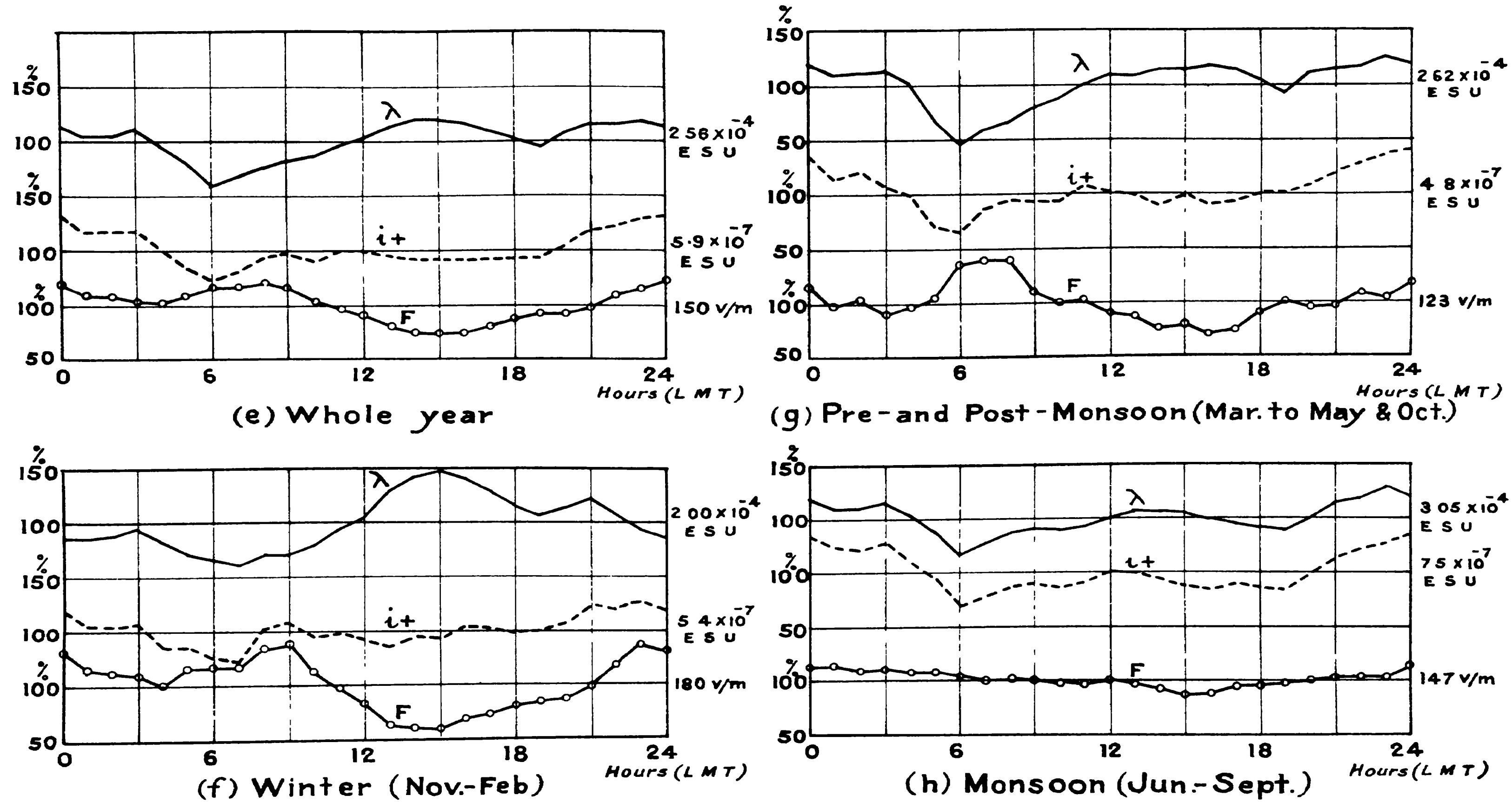

FIG. 3b. DIURNAL VARIATION OF POTENTIAL GRADIENT, CONDUCTIVITY AND AIR-EARTH CURRENT AT COLABA ON ELECTRICALLY QUIET DAYS (1935-36).

G P Z O POONA, 1938

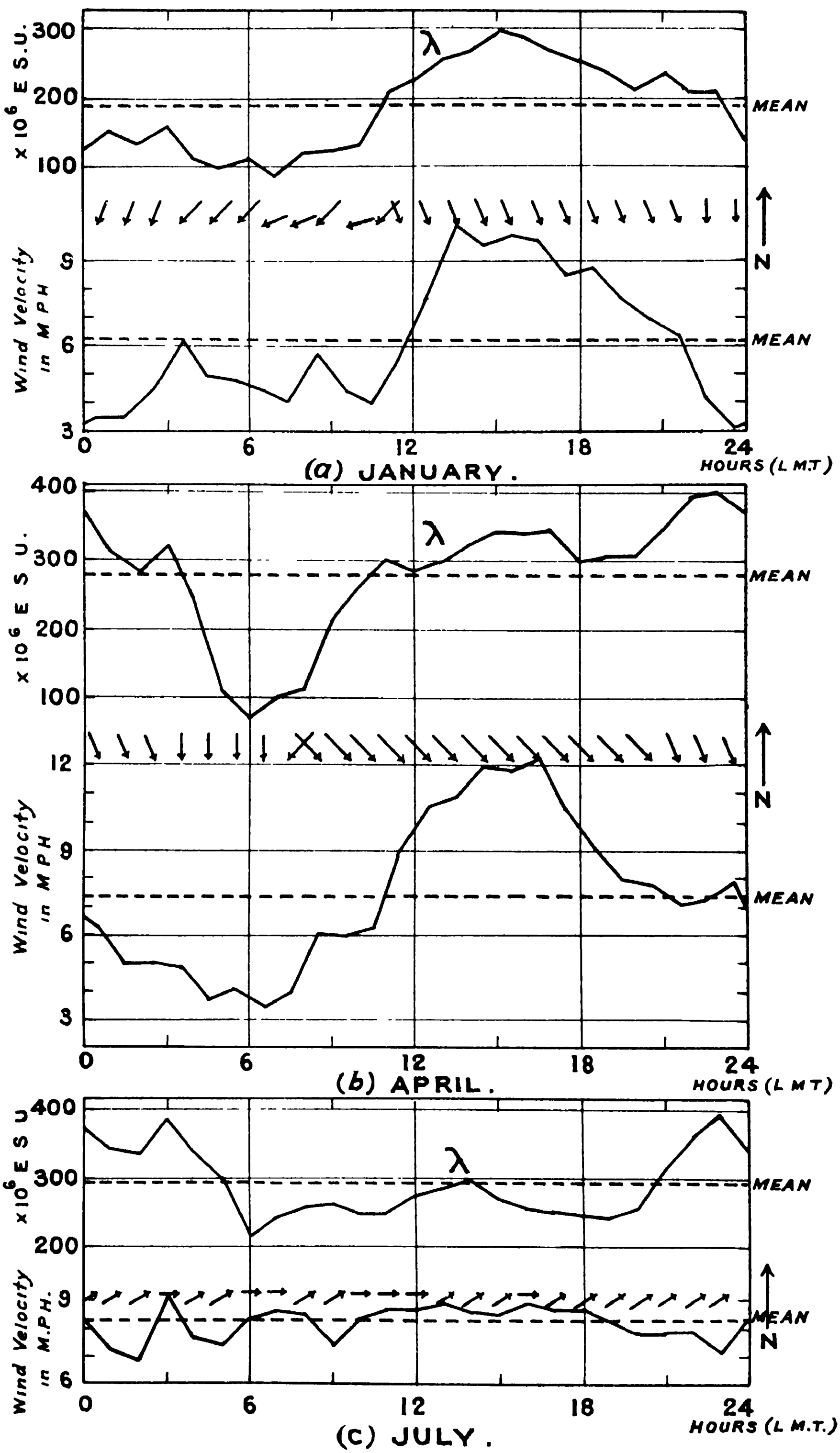

FIG. 4. DIURNAL VARIATION OF CONDUCTIVITY & WIND AT COLABA ON ELECTRICALLY QUIET DAYS.

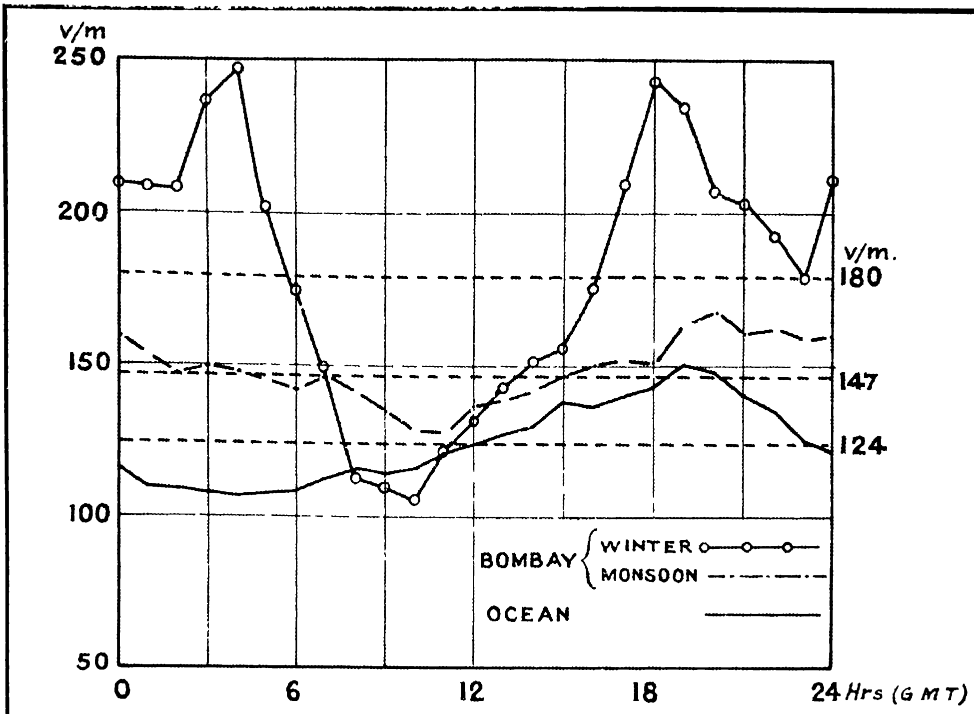

FIG. 5. DIURNAL VARIATION OF POTENTIAL GRADIENT AT BOMBAY AND OVER THE OCEANS.

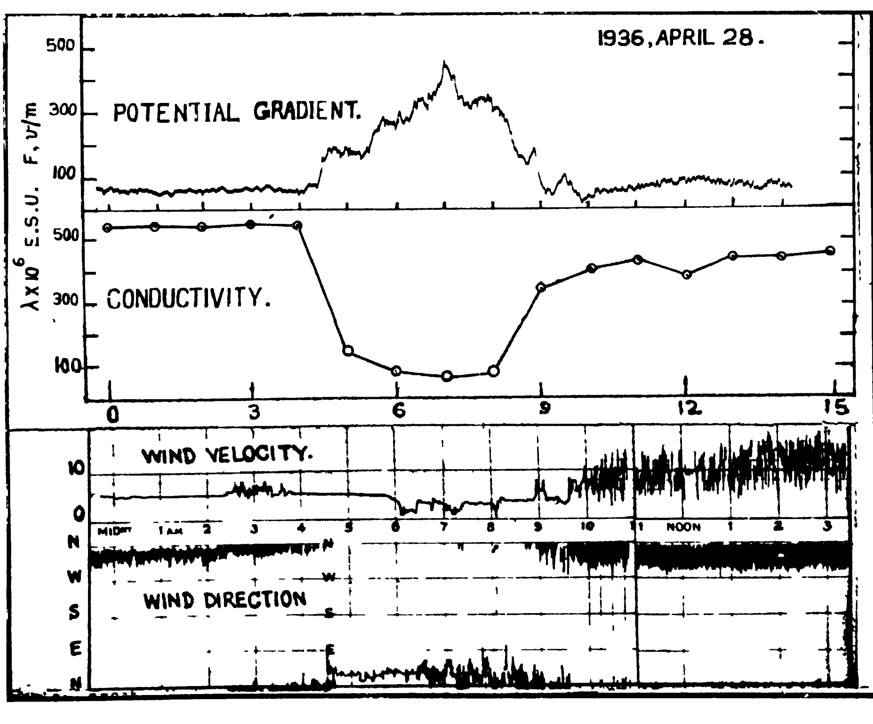

FIG. 6.

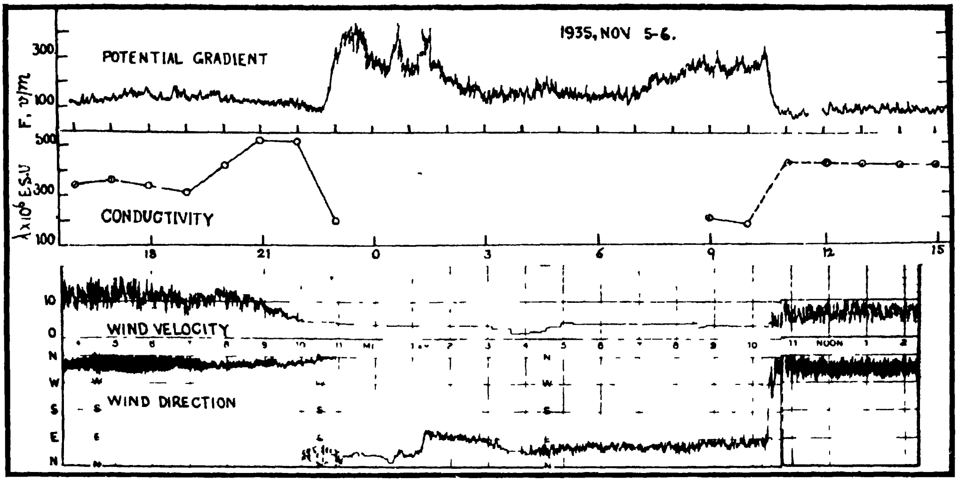

FIG. 7.

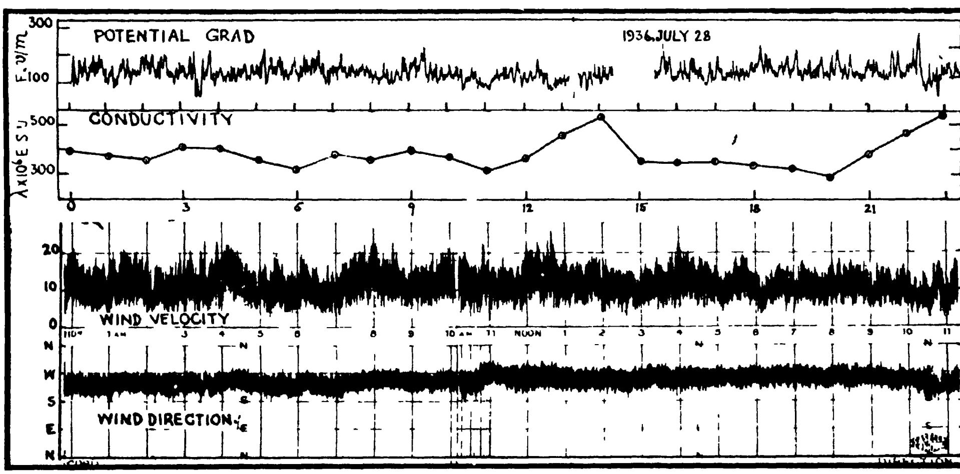

FIG. 8.

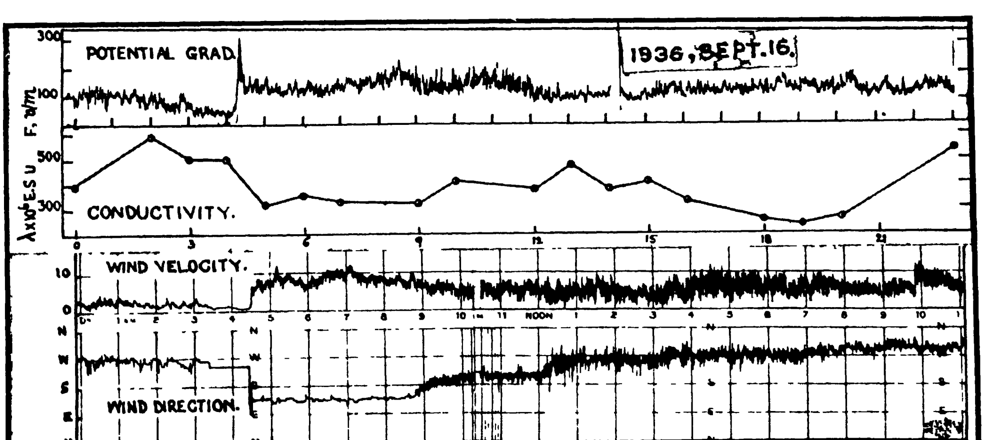

FIG. 9.

INDIA METEOROLOGICAL DEPARTMENT

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Average Intensity of Rainfall on a Rainy Day in India

BY

V. DORAISWAMY IYER AND KASTURINATH SOBTI.

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AVERAGE INTENSITY OF RAINFALL ON A RAINY DAY IN INDIA

BY

V DORAISWAMY IYER AND KASTURINATH SOBTI.

(*Received on 2nd September 1936, and in revised form on 29th August 1937*)

Abstract. Monthly charts of the average intensity of rainfall on a rainy day are prepared and discussed The average intensity associated with winter disturbances is found to be moderate The intensity increases gradually during the hot weather till a maximum value is reached in the monsoon During the height of the monsoon the chief feature of the distribution is the contrast between the windward and leeward sides of the mountain ranges In the retreating monsoon months the area of highest intensity lies along the coast of the Bay of Bengal

Under the rainfall organization of the Government of India, rainfall measurements are made daily at a large number of stations, the registration in each province being placed under the supervision of an officer of the Provincial Government The number of raingauges included in this organization was over 2,000 in the year 1900 and has now risen above 3,000

Rainfall in India is measured in inches correct to a hundredth of an inch Up to 1890 the India Meteorological Department followed the general practice of other meteorological services and adopted a rainfall of a hundredth of an inch or upwards in 24 hours as defining a rainy day During the reorganization of the system of rainfall registration throughout India which was effected in 1890, it was considered that in a tropical country like India a fall of 0·01″ in a day was too small to be of any value for agricultural purposes, and a fall of 0·10″, one tenth of an inch, in twentyfour hours, was selected as the most suitable for the definition of a rainy day. Since then rainy days have been calculated according to this convention and the normals of rainy days published are based on such figures.

The normals of rainfall and of the number of rainy days for all the raingauge stations based on data up to the end of the year 1900 were published in the *Indian Meteorological Memoirs, Volume XVII.* These data have also been used in the preparation of the normal charts of rainfall and of the number of rainy days in the *Climatological Atlas of India* Subsequently revised normals of rainfall and of the number of rainy days based on data up to 1910 were published in the departmental *Memoirs, Volume XXII, Parts I and II*, and normals based on data up to 1920 were published in *Volume XXIII, Part VII.*

In addition to the above data relating to rainfall, intensity of rainfall is an important climatic element Intensity may be calculated for each rainy day, each rainy hour or even shorter intervals of time depending upon the data available The present note deals with the average intensity of rainfall on a rainy day This element has not been discussed so far except for a brief mention by Blanford[1]. It seemed therefore worthwhile to calculate this figure for each month of the year and study its variation in time and space. In doing so the district was adopted as a unit more convenient to work with than the individual stations[2]. The district normals of rainfall, calculated with the help of the normals of individual raingauge stations based upon all data up to 1920, given in *Volume XXIII, Part VII*, of the departmental *Memoirs*, were utilised for the purpose From the district normals of rainfall and of the number of rainy days in each month, which are the arithmetical averages of the normals of all the stations in the district, the average intensity of rainfall on a rainy day in each district was calculated Thus in the month of January in the district of Sibsagar in Assam the normal rainfall is 1·06″ and the normal number of rainy days is 2·7 The average intensity of rainfall on a rainy day is therefore $1{\cdot}06'' \div 2{\cdot}7 = 0{\cdot}39''$ The values of average intensity thus obtained were plotted upon a district map of India and lines of equal intensity drawn at intervals of 0·2″ up to one inch and at larger intervals above one inch. These maps are shown in *Figs 1* to *13* at the end of the paper. The distribution is briefly discussed in the following paragraphs

January - The intensity is greatest being more than 0·8″, on the Coromandel coast, it decreases to less than 0 6″ in the interior of the Peninsula and increases again on approaching the west coast This distribution is apparently associated with the temporary revival of north-east monsoon conditions in the south of the Bay which gives the so-called 'Pongal showers' in south Madras A second region of high intensities exceeding 0 6″, found along the western Himalayas and the adjoining plains, is evidently associated with the western disturbances which pass across this region The intensity is less than 0·4″ in the dry tracts of northwest India as well as in upper Assam and the Irrawaddy valley

February —The region of moderately high intensity on and near the western Himalayas persists The maxima on the Coromandel coast give place to maxima over Pegu, presumably an effect of thundershowers The distribution is nearly uniform along the coast from Malabar to Arakan

March —The beginning of the spring thunderstorms known as "Nor'westers" over Bengal and Assam is indicated by the increase of intensity in these regions. High figures continue in parts of Lower Burma

(1) *Blanford.*—Climates and Weather of India, pp 75—76 and 259

(2) This helped not merely to minimise the labour involved, as it was enough to calculate values for about 350 districts instead of for over 3,000 stations, but it gave also a clearer picture of the general distribution of this element over India than the more variable figures of individual stations.

April.- There is a further increase of intensity over Burma, Assam and east Bengal, the figures being nowhere below 0·4″ in these provinces The average fall per rainy day is over 1·25″ on the Khasi hills and exceeds an inch in Cachar and Sandoway The noteworthy change in north-west India is the increase in Cutch and lower Sind.

May. There is a general increase of intensity throughout India, the figures exceed an inch along the Burma coast except where the hills are interrupted by the Irrawaddy delta, and approach an inch along the west coast of the Peninsula. High values continue in east Bengal and south Assam, the maximum of 1·7″ occurring in the Khasi hills

June With the setting in of the monsoon in June the striking feature of the intensity distribution is the contrast between the windward and leeward sides of the mountain ranges on the west coast of the Peninsula and on the Burma coast. On both these coasts the figures exceed 1·5″ in places, and probably rise to higher values on the hills as exemplified by Mahabaleshwar with its average of 2″, but rapidly fall off to less than 0·6″ in the interior of the Peninsula and of Burma. The average fall exceeds 1·5″ near the Sikkim Himalayas and is nearly 3″ on the Khasi hills. The lowest intensity of less than 0·2″ occurs in the extreme northwest of Baluchistan

July – The distribution is in the main similar to that in June in the Peninsula and Burma The main change from June to July in northern India is a decrease in lower Bengal, an extension of the region of high intensity along the Himalayas up to the Punjab and an increase in northwest India due to the extension of the monsoon in association with the westward passage of depressions from the Bay

August The August chart shows a decrease of intensity on the west coast of the Peninsula and on the Burma coast together with a slight increase in the east of the Peninsula and in the interior of Burma, and a consequent diminution in the contrast between the two sides of the mountain ranges In northern India the chief change is a decrease in the Khasi hills and in lower Sind

September There is a further decrease of intensity on the west coast of the Peninsula as well as on the Burma coast, and the contrast between the windward and leeward sides of the coastal ranges disappears in the Peninsula, but is still noticeable in Burma There is an increase in northwest India especially on and near the Punjab-Kumaon hills, due to the fact that storms from the Bay break up in these hills in this month In the Khasi hills the intensity is 1·7″, the same value as in May

October With the retreat of the monsoon over the Bay and its setting in as the 'northeast monsoon' in Madras there is an increase in this month along the east Madras coast The high intensity in the submontane region from the east Punjab to Assam persists, indicating that, though occasions of rain are rare, the falls are as heavy in October as in September which has a much higher rainfall There is generally a decrease over the rest of the country It is interesting to note that the mean intensity over India as a whole is the same in this month as in the pre-monsoon month of May, but the distribution is different while in May there is a concentration of high intensity over northeast India with a rapid decrease westwards, the contrasts are less marked in October and the highest intensity is found along the Himalayas and on the coast round the Bay of Bengal.

November.—The sub-Himalayan strip of high intensity which persisted in the monsoon months has disappeared, and there is also a general decrease over the whole country, except on the coastal strip round the Bay of Bengal where the 'northeast monsoon' continues to be active; the higher figures on the Orissa and Arakan coasts seem to be associated with the storms of this month.

December.—The only regions where the intensity exceeds 1·0″ are the Coromandel and Circars coasts, but intensity decreases rapidly on passing inland. The intensity is below 0·6″ over most of the country outside the Peninsula and is below 0·4″ in south Rajputana, lower Sind and Gujarat.

Year.—Taking the year as a whole the intensity exceeds 2·0″ on the Khasi hills, is over 1·5″ on the Arakan coast, and lies between 1·0″ and 1·5″ all along the west coast of the Peninsula, in Tenasserim and in a few districts of Bengal. Over the remainder of the country the intensity is mostly between 0·6″ and 1·0″, and falls below 0·6″ only in the southwest Punjab, the North-West Frontier Province and Baluchistan, and in parts of the Deccan plateau and of the Shan States.

The main features of the distribution of intensity of rainfall in India may be summarised as follows:—

(1) The average daily precipitation associated with western disturbances which travel across northern India in the winter months does not exceed 0·8″ even on the hills, while in the plains it is below 0·4″ in some parts of northwest India and Burma.

(2) During the hot weather months the average intensity is least in northwest India and is highest in Assam, east Bengal and on the Burma coast. With the advance of the season there is a general increase of the average intensity, the mean for the whole of India being half an inch in March and fourfifths of an inch in May. This appears to be mainly due to the fact that the cold air masses which flow over India in winter are replaced gradually by the warmer and more humid air from the surrounding seas.

(3) During the monsoon months the striking feature of the distribution is the sharp contrast between the windward and leeward sides of the mountain ranges which lie athwart the monsoon current. With the advance of the season, when the monsoon weakens, the contrast between the two sides of the mountain ranges becomes less marked.

(4) During the months of October to December when the monsoon recedes to lower latitudes in the Bay of Bengal the chief factors controlling the distribution of the intensity of rain are the tracks of the post-monsoon storms and the setting in of the 'northeast monsoon' on the Coromandel coast.

Extreme examples of heavy falls are to be found in the Khasi hills and on the Western Ghats. Over the Khasi hills as a whole the average intensity is nearly three inches in June and July, and about two and a half inches in August. Taking individual stations the average intensity is three and three quarters of an inch at Cherrapunji in June and July, while at Mawsynram, which is situated in a similar high valley at a distance of 10 miles from Cherrapunji as the crow flies and at a slightly higher elevation, the average intensity is nearly four inches in May and August, four and a half inches in July and five inches in June. At Mahabaleshwar

on the Western Ghats the average intensity is three and a half inches in July and two and a half inches in August. Further south on the Western Ghats, at Agumbe and Byrapur Estate in Mysore, the average intensity is three and three quarters of an inch in July and about two and a half inches both in June and August.

It may be mentioned that the brief discussion of this element by Blanford[1] is based on the general average for the year and his number of rainy days included all days of rain of 0·01″ and above His figures were therefore strictly comparable with figures in Britain He concluded from such a comparison that, day for day, rainfall is three to seven times as heavy in the plains of India as in western Europe The restricted count which is in use from 1891 decreases the number of 'rainy days' and hence gives a higher value for the average intensity Hence the intensity figures given in this paper are higher than those obtained by Blanford, especially in regions where light rain of less than 0·10″ is more common in certain seasons of the year His further observations apply with greater force to the present figures, and they are quoted below " The common proverbial expression 'it never rains but pours' is a literal expression of the rainfall of India This is as true of such places as Jacobabad and Multan where there are no more than about fourteen rainy days in the year as of Point de Galle where it rains on 205 days on the average ".

(1) Loc Cit

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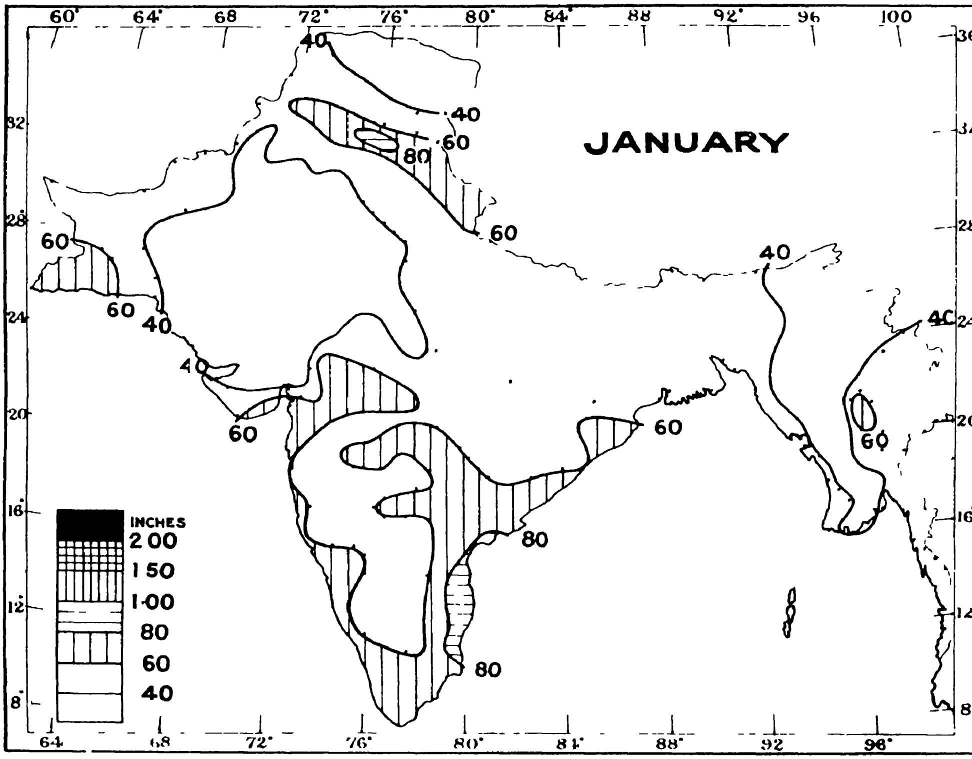
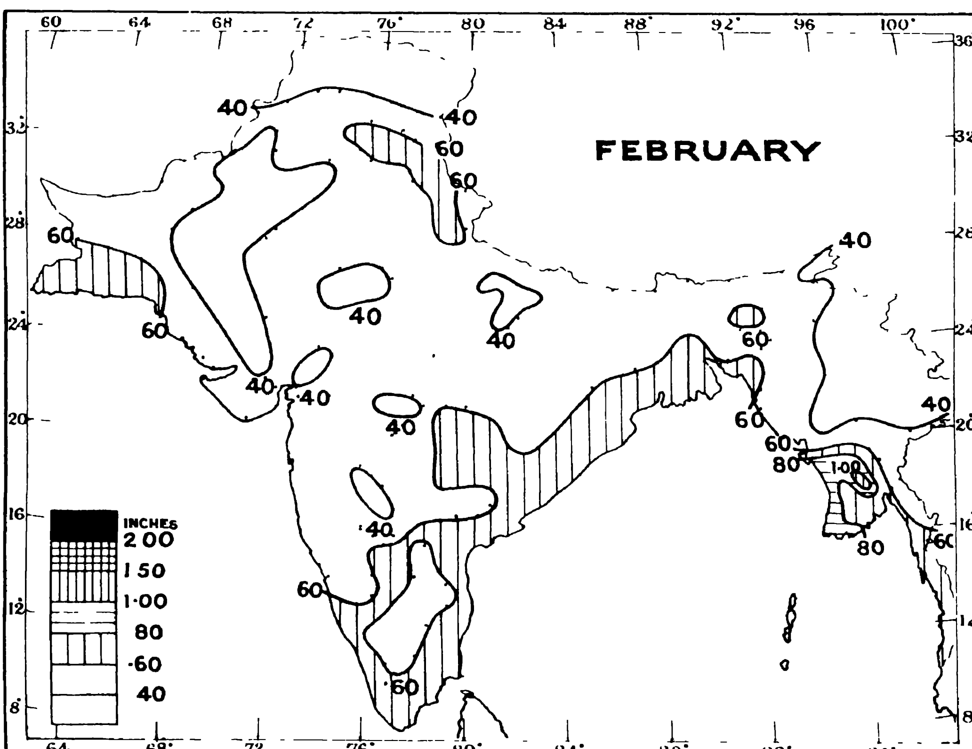
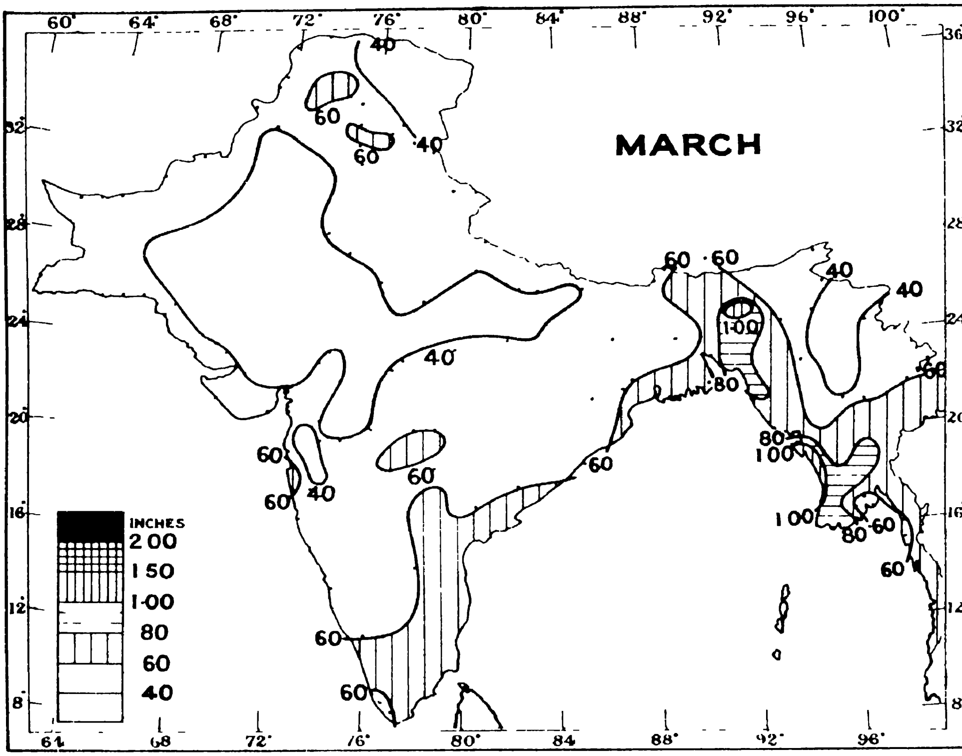
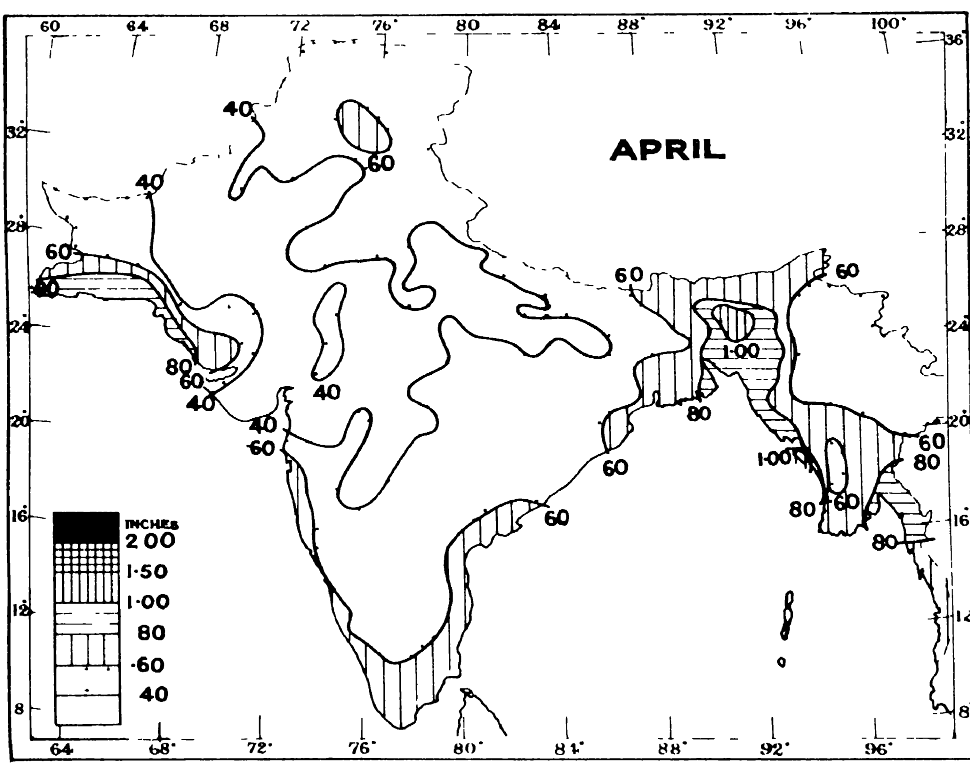


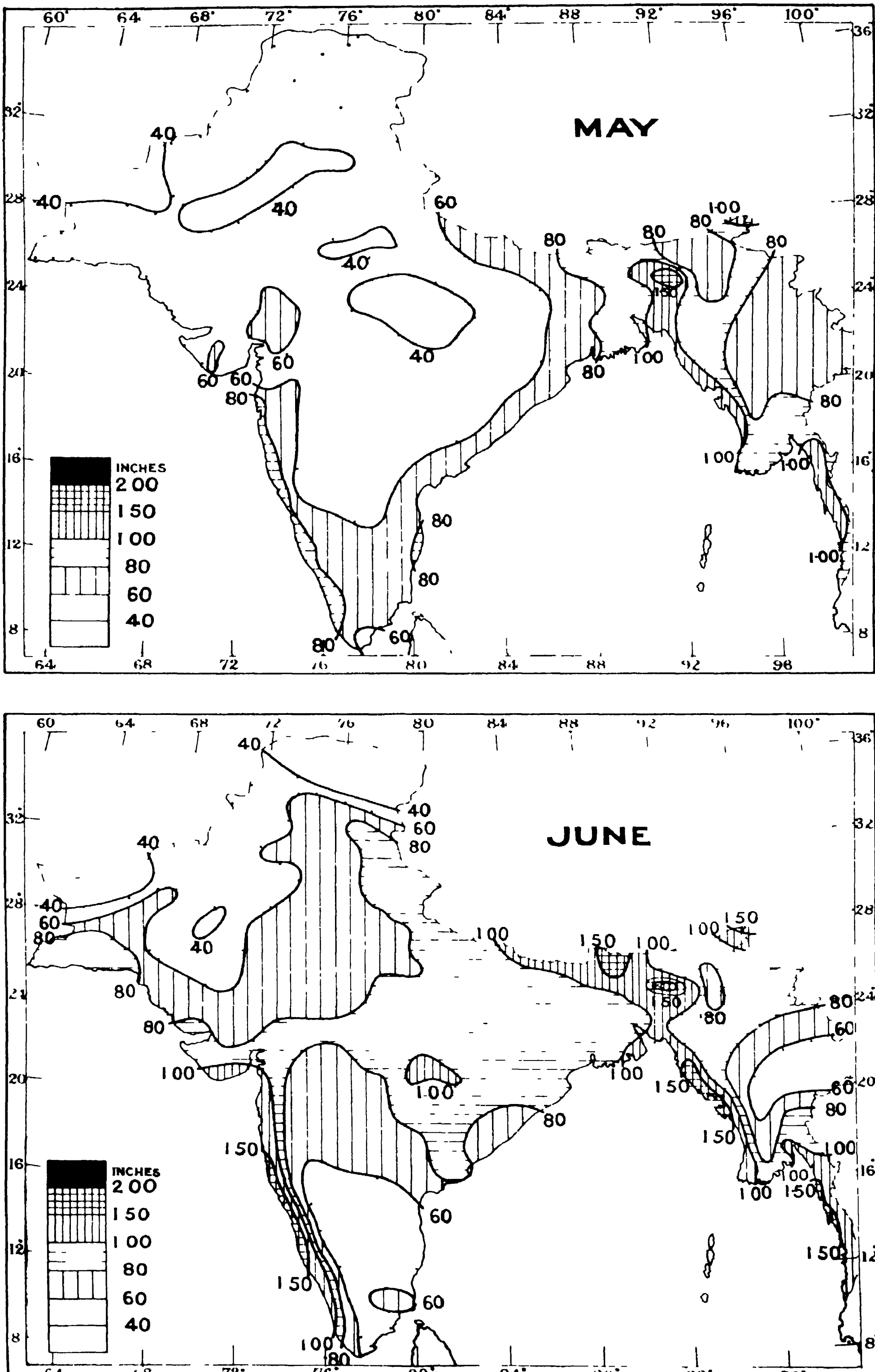


Figs 1-2 Average intensity of rain on a rainy day-
January and February

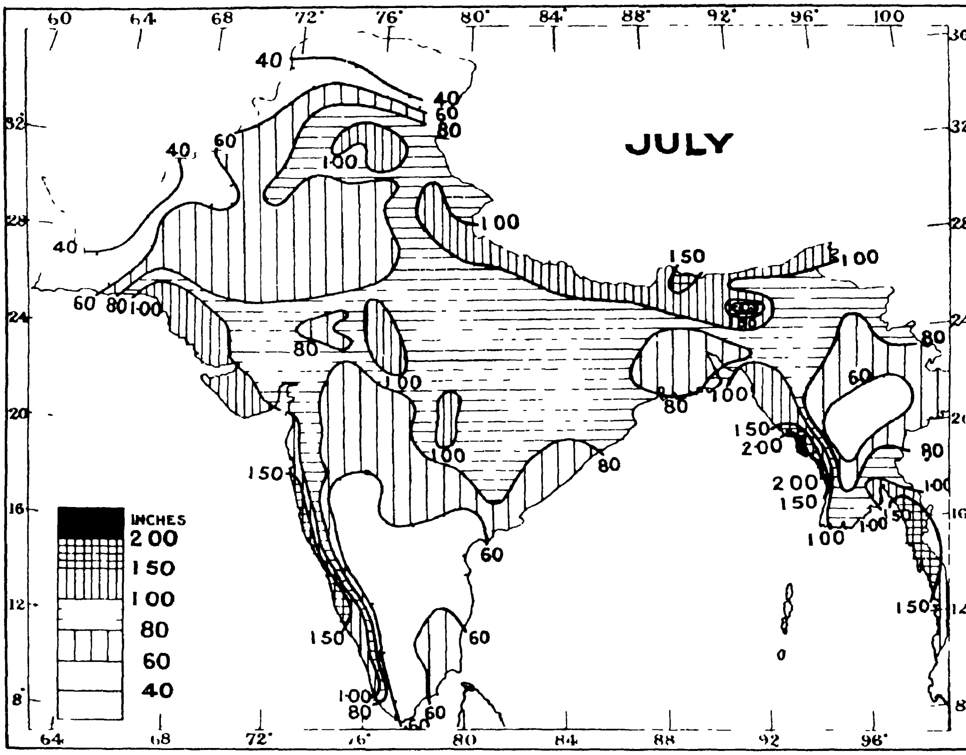


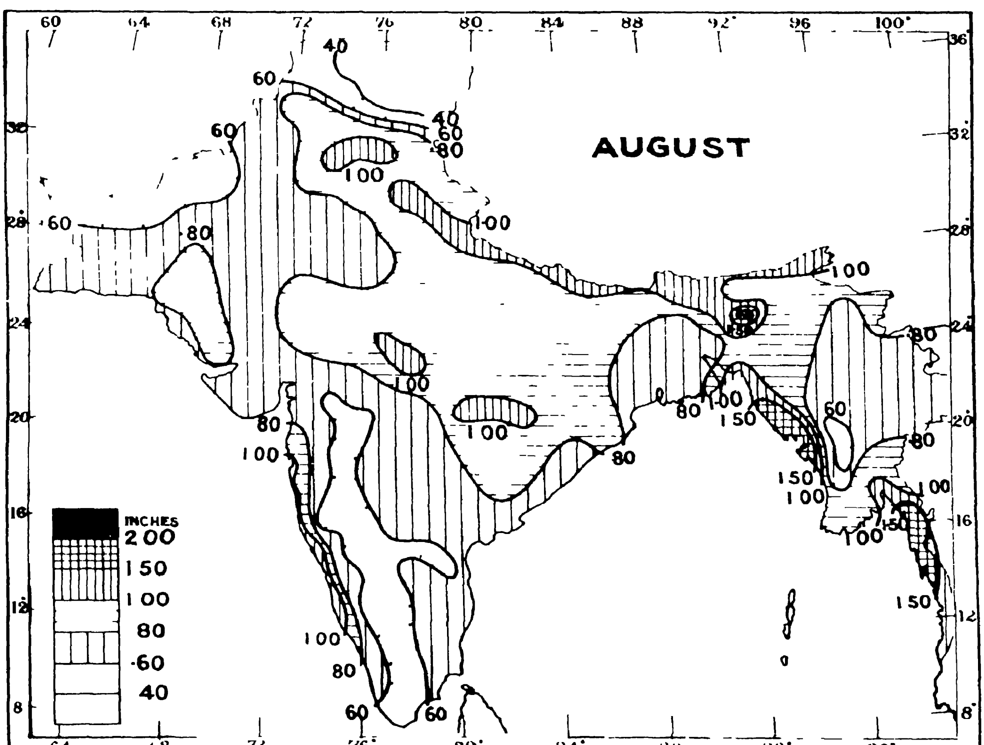


Figs. 3-4 Average intensity of rain on a rainy day
March and April

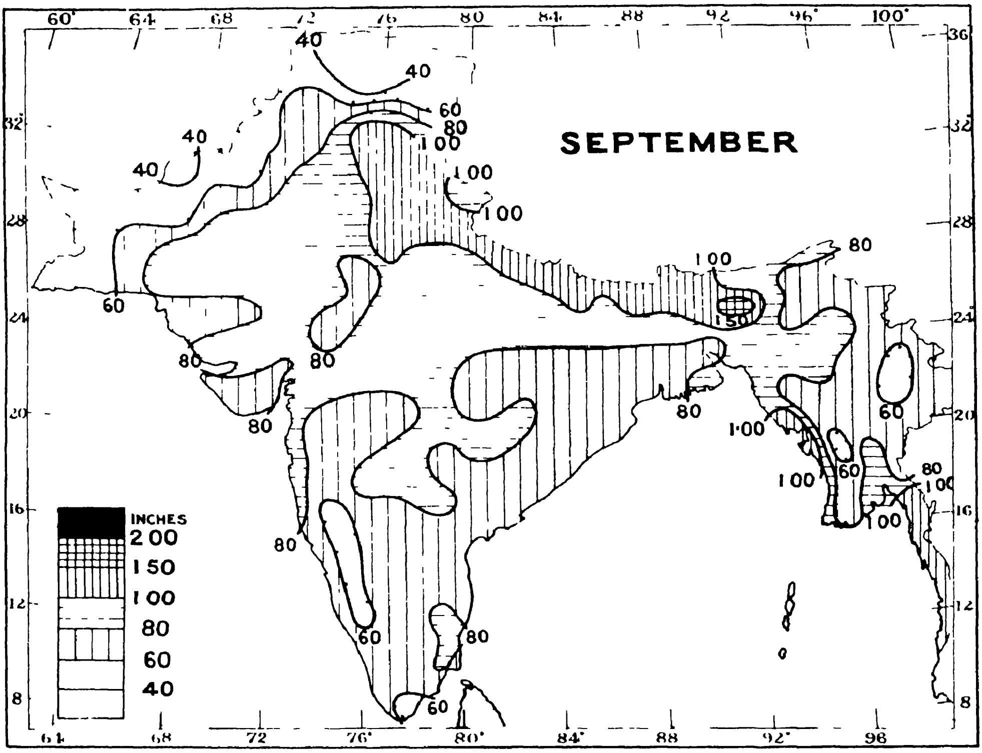


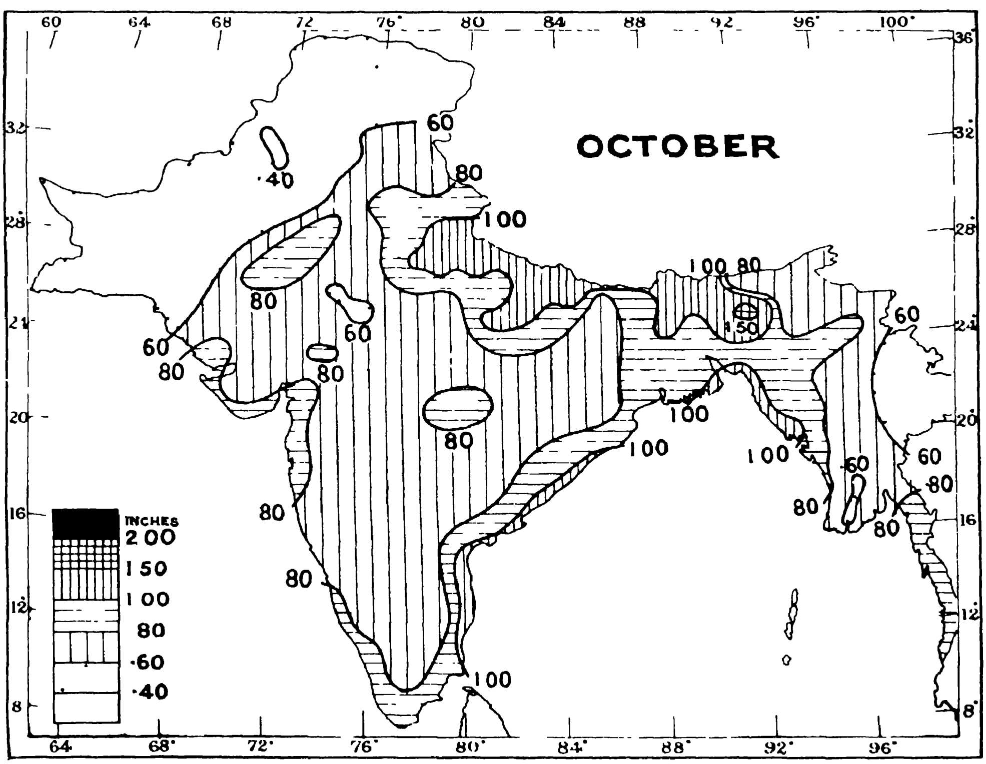
Figs 5-6 Average intensity of rain on a rainy day May and June



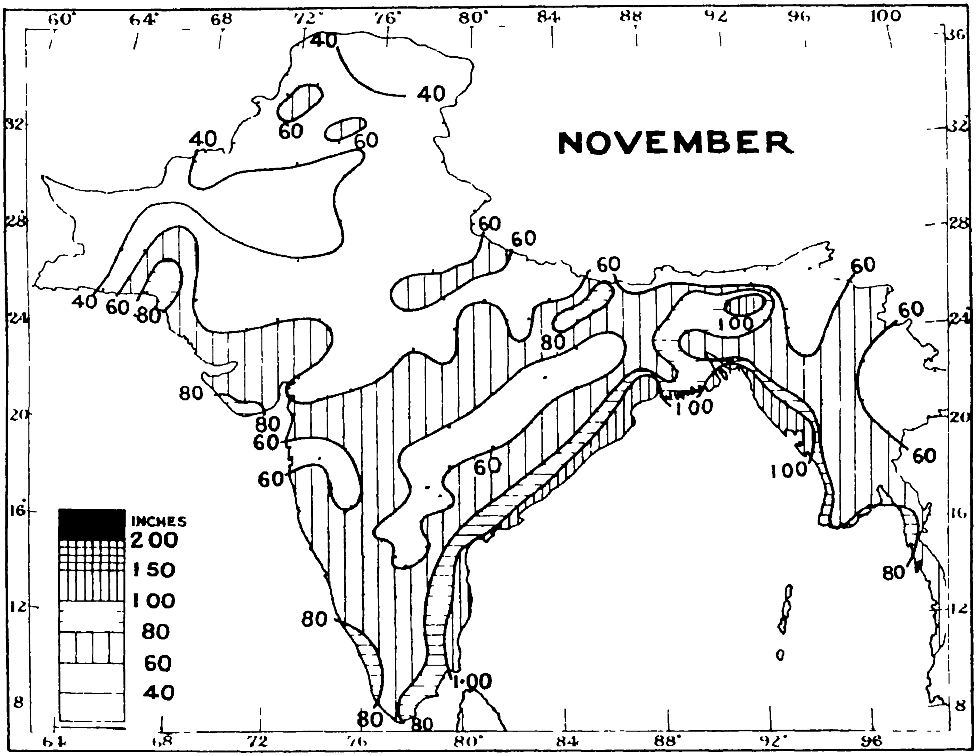


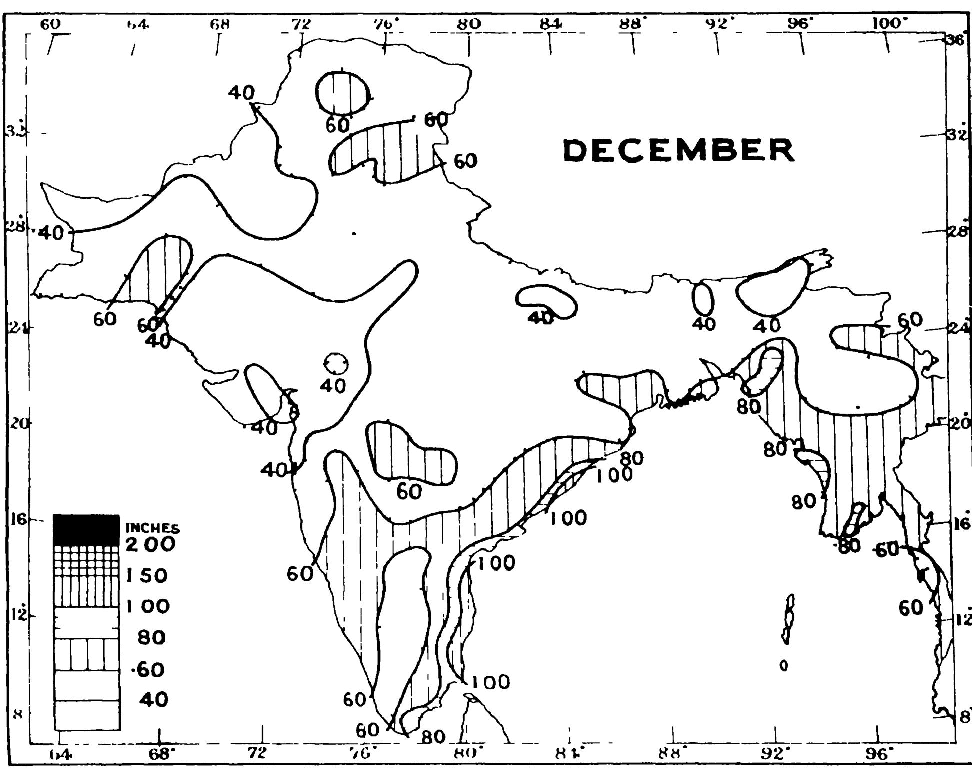
Figs 7-8 Average intensity of rain on a rainy day
July and August





Figs. 9-10 Average intensity of rain on a rainy day September and October





Figs 11-12 Average intensity of rain on a rainy day November and December

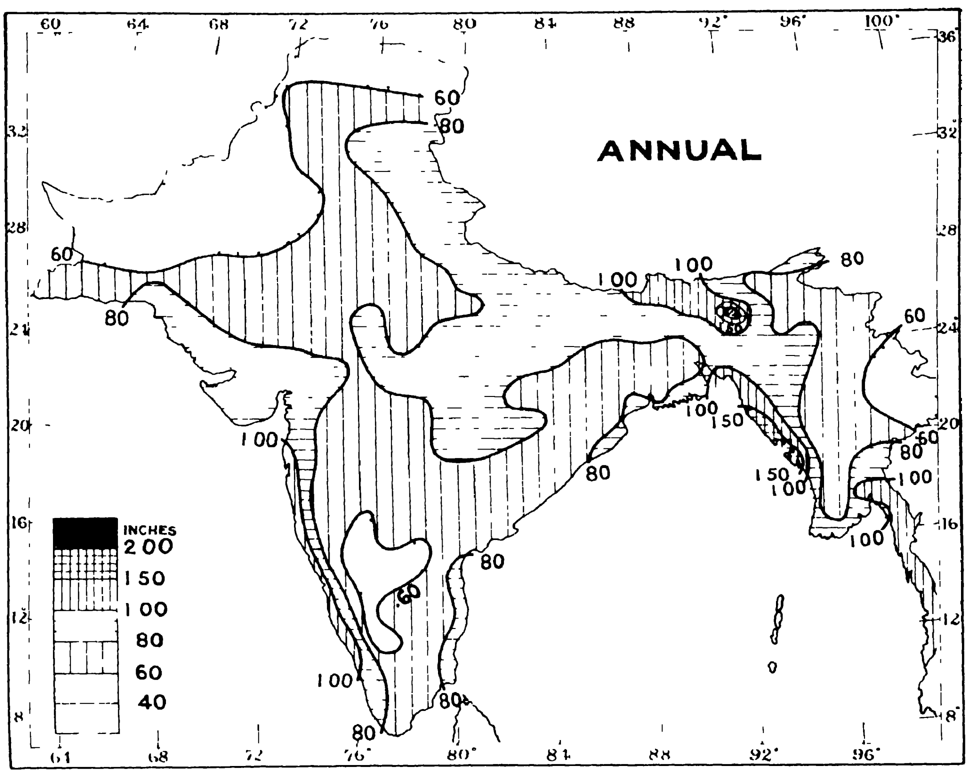


Fig 13 Average intensity of rain on a rainy day
Year.

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INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. VII, No. 73

Daily Variations of Temperature and Pressure at Different Levels over Agra associated with Passage of Western Disturbances

BY

S. P. VENKITESHWARAN.

(Received on 9th May 1935, and in revised form on 3rd September 1936.)

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551.511

DAILY VARIATIONS OF TEMPERATURE AND PRESSURE AT DIFFERENT LEVELS OVER AGRA ASSOCIATED WITH PASSAGE OF WESTERN DISTURBANCES

BY

S. P. VENKITESHWARAN.

(*Received on 9th May 1935, and in revised form on 3rd September 1936.*)

Abstract.—The paper describes the day to day changes of temperature and pressure at different heights over Agra obtained from a series of sounding balloon ascents made almost every day during the period January—March, 1931. It is observed that the rapid decrease of lapse rate usually observed at about 12-13 kms. over Agra during these months is associated with a fall of temperature practically at all heights below 12 kms., a rise of temperature above this height, and a fall of pressure extending practically throughout the troposphere over Agra. An example of this effect was also furnished by some ascents made in January—February, 1929. Instances have also been observed in which increase in lapse rates occurred in this region, and these were associated with a rise of temperature at levels below about 12 kms., a fall above and a rise of pressure at all heights. It is therefore suggested that both the decrease and the increase in lapse rates in this region may be the results of advection over Agra from higher and lower latitudes respectively.

In the India Meteorological Department, the nature of the transition from the troposphere to the stratosphere has been classified into four types, of which the types I, II and III are defined according to the same conventions as those in use at the London Meteorological Office, while the type IV is a composite type in which the transition takes place in two stages. In this composite type, the lower transition occurs mostly at about 12-13 gkms. and the upper one at about 16-18 gkms. The lower transition varies from a sharp decrease of lapse rate to even a strong inversion, while the upper one is invariably an inversion, the region between the two having the lapse rate varying from 3° to 6 °C/gkm.

During January to April 1931, sounding balloon instruments were let off from Agra almost every day; the instruments retrieved gave a few sets of records of upper air temperatures and pressures for consecutive days. From an analysis of these data, it is found that the formation of the inversion at the 12 gkms. level is generally associated with a fall of temperature below this level and a rise above. It is also accompanied by a fall of pressure at all heights. A few typical examples are described below.

Case I.—31st January to 2nd February, 1929—A sounding balloon instrument let off on 31st January 1929 during the passage of a cold wave showed that at about 10 kms. and above, the temperature distribution over Agra was nearly isothermal, and it appeared as though the stratosphere began at a height as low as 10 kms. Following the wake of a western disturbance, the cold wave made its first appearance over India on the 25th of January 1929, when a general fall of temperature occurred along the Frontier hills The western disturbance lay as a low pressure area over east Rajputana and central India on the 25th, it moved to the Central Provinces on the 27th and filled up on the 28th During this period, the cold wave was steadily moving eastwards. The seasonal high pressure area over north-west India began to intensify steadily from the 29th January and it spread over practically the whole of north India by about the 1st February. A second western depression affected the extreme north on the 30th and it rapidly moved to east Central Provinces on the 31st, filling up on the 1st February. The anticyclone probably reached its maximum intensity on the 1st February, when the pressure departures at 8 hrs. on the surface were of the order of $+ 0{\cdot}150''$ in the region of its centre. Its intensity began to decrease from the 2nd February.

Temperatures and pressures at different levels over Agra on the 25th and 31st January and 2nd February 1929 are given in *Table I* and shown diagrammatically in *Figs. 1* and *2* On the 31st January, on which date the cold wave nearly reached its climax, the temperature was below that on the 25th at all heights up to 10 gkms, while above this level it was higher, up to the available height of 15 gkms Pressure on the other hand fell appreciably at all levels except on the ground. The temperature on this day was below normal* up to 12 gkms. while above this height it was above normal The pressure was below normal at all levels except on the ground.

On the 2nd February, the intensity of the cold wave had definitely decreased on the ground The sounding balloon record for the day showed that the temperature had risen above that on the 31st at all levels up to 10 gkms, while it fell at higher heights. Pressure also rose practically at all heights.

Similar changes of temperature and pressure over Agra, but, on a smaller scale, observed during the winter months of January—March 1931, are described below.

TABLE I.

Ht. (Gkm)	Normal (mean of Jan & Feb)	25-1-29	31-1-29	2-2-29	Ht (Gkm)	Normal (mean of Jan & Feb)	25-1-29	31-1-29	2-2-29.
		Temperature					*Pressure*		
Ground	294 0	293 0	285 0	288 4	Ground	994	993	996	996
1	287 0	289 6	276 7	282 7	1	901	900	897	900
2	282 5	283 5	276 2	279 9	2	797	798	791	794
3	275 5	276 7	269 3	273 1	3	703	704	698	701
4	269 5	268 7	263 9	266 4	4	619	620	611	615
5	263 5	261 2	256 6	260 3	5	543	544	536	540
6	256 0	254 9	249 5	253 2	6	475	475	466	471
7	249 5	247 8	243 1	241 6	7	413	413	405	408
8	242 5	240 0	236 4	237 1	8	359	358	350	354
9	235 0	232 3	228 0	229 0	9	310	309	301	305
10	228 0	223 4	220 3	223 8	10	267	265	259	261
11	222 0	217 1	220 4	217 5	11	227	227	221	224
12	217 5	213 0	220 3	217 7	12	195	193	188	191
13	213 0	213 0	217·2	213 1	13	167	164	161	162
14	211 0	213 8	218 3	211 2	14	141	139	137	137
15	207 0	213 0	216·2	211 3	15	119	118	117	117
16	204·0	211·6	..	213 7	16	101	100	..	98 5
17	202 5	209·4	..	..	17	85	85	..	..

*The normals have been calculated from the soundings from 1925 to 1933

Case II.—29th to 31st January 1931.—The weather in the region of Agra may be briefly described as being fair from the 25th to the 31st. A western disturbance was active over Baluchistan on the 31st. Moving eastwards it lay as a low pressure area over the south-east Punjab and southern parts of the United Provinces on the morning of the 2nd February.

Fig. 3 represents the temperature-height diagrams from the ascents made during these days, and *Fig. 4* shows the isopleths of temperature and pressure drawn from these data

From the 29th to the 31st there was a rise of temperature practically at all heights up to about 10 gkms., above which the temperature fell. There was also a corresponding rise of pressure at all heights during these days There was a well-marked inversion at about the 12 gkms. level on the 29th and it became gradually less and less marked until the 31st with the temperature and pressure changes as observed above.

Case III.—13th to 20th February 1931.—On the 13th a western disturbance was affecting Baluchistan It moved eastwards on the 14th causing general rain in the North West Frontier Province and Kashmir, and a few falls in Sind, south-west Punjab and the Punjab hills It caused light showers in west Rajputana and the United Provinces on the 15th, and it appeared as a shallow low pressure area over the Central Provinces on the 16th A fresh western disturbance affected the North West Frontier on the 17th and moving eastwards merged into the low pressure area over the Central Provinces on the 19th , it filled up on the 23rd.

From *Fig 5a* it can be observed that from the 13th to the 15th, there was an appreciable fall of temperature up to 11 gkms. and a rise at all levels above this height up to 15 gkms Above this height there was no large change. Pressure fell at all heights (*Fig 5b*) *Fig 7* shows how a well-marked inversion resulted at the 12 gkms level with the above temperature and pressure changes.

From the 15th to the 16th, there was comparatively little change in temperature up to 6 gkms , but above this there was an increase up to 10 gkms , from 11 gkms. up to the base of the stratosphere at about 15 gkms temperature decreased.

The ascent on the 17th reached only 13 gkms. but it shows that from the 16th to 17th there was a general fall of temperature up to 10 gkms and a rise above associated with a fall of pressure above 4 gkms.

From the 17th to the 20th there was a gradual and general rise of temperature from about 5 to 12 gkms above which there was either no change or a slight fall. There was a corresponding rise of pressure at 5 gkms. and above

From the 15th to the 20th, though there were no large changes in temperature and pressure from day to day, yet one can see a tendency for the variation to follow the general law indicated above

Case IV.—9th to 17th March 1931.—The weather during the period 9th to 13th March was generally fair. A western disturbance affected Baluchistan on the 13th, and on the 14th it lay as a low pressure area over the region extending from upper Sind to west Central India. On the 15th, it was over south-west Punjab and Rajputana. On the 16th, it weakened and moved over Bihar and Orissa. On the 17th a cyclonic circulation at and above 2 kms. was observed over north Punjab and Kashmir. On the morning of the 18th, this was not visible up to 6 kms., but the cirrus movement indicated a definite cyclonic circulation over east Punjab and west United Provinces.

Figs. 6*a* and 6*b* are the isopleths of temperature and pressure for this period. On the 10th the temperature was lower than that on the 9th at all levels above 5 gkms. up to 12 gkms., and above this height it was higher. The pressure on the 10th was lower than that on the 9th at all levels above 5 kms.

From the 10th to the 12th the temperature rose at all heights up to 11 gkms., above which it fell, the pressure correspondingly rising at all heights. This was followed by further but slow rise in temperature practically at all heights till the 16th. There was a gradual but slight increase of pressure also at these levels during these days.

The inversion at 12 gkms. was gradually wiped out and there was no trace of it on the 15th

The lapse rate of temperature on the 10th, 12th and the 15th at the levels of the lower transition, *viz.*, at about the 12 gkms level, is given below in *Table II*. It was lowest on the 10th, and on this day the temperature at levels below 12 gkms. was lower than that on the 9th and higher at the higher levels The lapse rate was highest on the 15th and was associated with the temperature and pressure changes described above.

TABLE II

Date	9-10 gkms	10-11 gkms	11-12 gkms	12-13 gkms
10th March 1931	3·5°C	5·0°C	1·0°C	4·5°C
12th March 1931	8·0°C	7·5°C	8·5°C	4·5°C
15th March 1931	6·0°C	9·0°C	9·5°C	6·5°C
Normal for March	6·9°C	5·5°C	5·1°C	4·9°C

Fig. 8 illustrates the distribution of temperature with height on the 10th, 12th and 15th

On the 17th there was a large fall of temperature at all heights above 6 kms. extending up to 18 kms This was associated with a large fall of pressure of the order of 4 mbs at some heights especially above 10 kms Probably this was related to the cyclonic circulation observed on the morning of the 18th at the cirrus level and referred to above.

Case V.—23rd to 31st March 1931.—The weather was dry over the country till the 25th, on which day a western disturbance caused a few falls of rain in the North West Frontier Province. On the 27th morning a diffuse low pressure area appeared over east Punjab and the west United Provinces This low pressure area was over the United Provinces and the east Central India on the 28th and it persisted over there till the 30th. It filled up on the 31st

From the 23rd to 28th (see *Figs.* 9*a* and 9*b*) the temperature diminished gradually at all levels above 3 gkms. up to 13 gkms and above this it gradually increased. There was also a gradual diminution of pressure during these days at all heights. But from the 28th to 30th there was an appreciable fall of temperature at all heights up to 9 gkms., above which the temperature increased. Pressure also fell at all heights. From the 30th to 31st there was rise of temperature at all heights up to 9 gkms. and a fall up to 13 gkms., and little or no change above. Pressure rose at all heights during this interval.

It is interesting to note the gradual development of inversion at 12 gkm level from the temperature height curves for the period 23rd to 31st, given in *Fig 10*

It is observed in the cases described above that the occurrence of the lower transition in the region of about 12 gkms. (type IV of the nature of transition from troposphere to stratosphere) is associated with a fall of temperature at all heights below that level and a rise above, accompanied by a fall of pressure at all levels

Dr. Ramanathan and Mr. Ramakrishnan[1] have suggested that this lower transition may be due to a " meridional movement of air in the neighbourhood of the tropopause, the upper transition corresponding to the tropopause of tropical latitudes and the lower one to that of temperate latitudes ". They have suggested that this may be the result of the ring of cold air which collects near the tropopause over tropical latitudes tending to spread out with a slight downward component towards higher latitudes, to compensate for which there is a movement in the lower levels towards lower latitudes, producing thereby a kink in the tropopause in the region of maximum rate of variation of height in the tropopause with latitude The lower boundary of the spreading equatorial air has been estimated to be in the neighbourhood of 12 gkms[2]. From the changes of temperature associated with the formation of this lower transition observed in the different cases described in this paper, it appears that it may also be explained by a simpler hypothesis

From a comparison of the monthly normals of temperature and pressure for Agra (Lat 27°1'N, Long 78 05'E) and Poona (Lat 18 32' N, Long 73°51' E) [3] during December to April, it will be observed that the temperatures at all levels up to 12 gkms are lower over Agra than over Poona, and above this height Agra is warmer than Poona The pressures over Agra are lower than those over Poona during these months at practically all heights except near the ground up to 1 gkm It may therefore be assumed that, at the same level, the temperature decreases to the north of Agra below 12 gkms and it increases above this height If, therefore, during this season there is a movement (not necessarily by the same amount at all heights) of air extending up to the stratosphere from higher latitudes to Agra, the temperature will fall at all heights below 12 kms while it will rise above this height and this may result in a decrease of the lapse rate already existing at about the 12 kms level These changes will be associated with a fall of pressure at all levels provided there are no other disturbing causes The decrease in the lapse rate may also occur even if this advection from the north occurs only at some particular heights above or below this level The general circulation is westerly over Agra during this season and therefore the effect described above may be observable over Agra even if the north to south advection occurs in some region to the west of Agra Similarly one may expect higher lapse rates than the existing one to occur at this level when there is movement of air over Agra from lower latitudes. This will be associated with a rise of pressure at all levels.

I must thank Mr G Chatterjee, Meteorologist-in-charge, Upper Air Observatory, Agra, who was responsible for the collection of data described in this paper, and Dr. N K. Sur and Mr S L. Malurkar for some valuable criticisms.

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[1] Mem. Ind Met. Dep, Vol. XXVI, Part IV, p. 53.

[2] Nature, Vol 132, p 932.

[3] Mem. Ind Met Dep Vol XXV, Part V & Vol. XXVI, Part IV.

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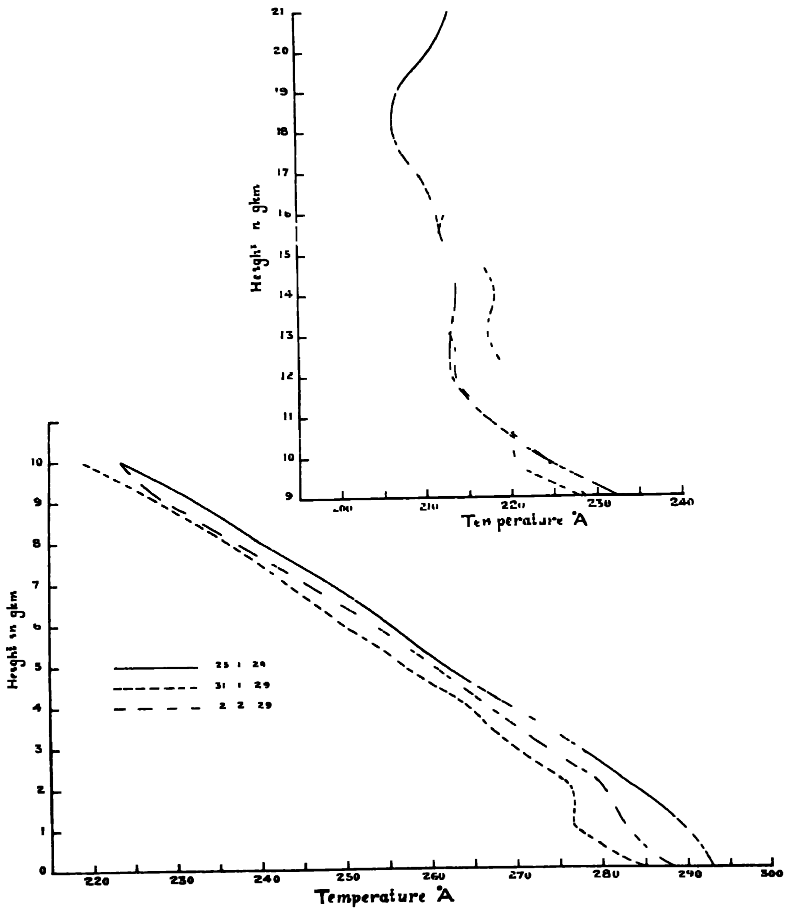
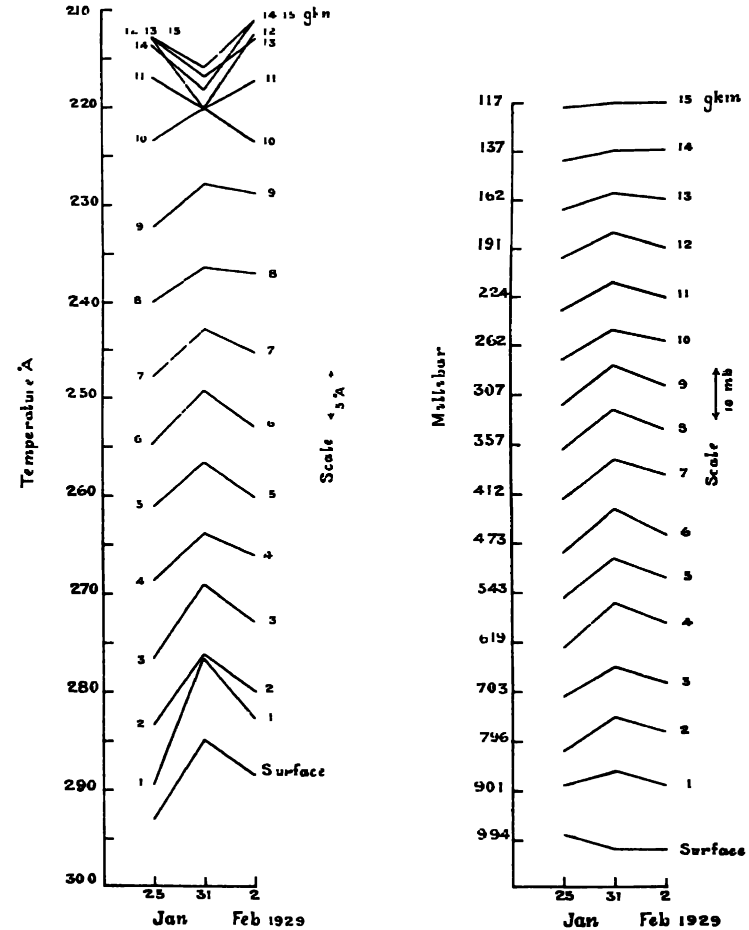


Height in gkm
Temperature °A
25 1 29
31 1 29
2 2 29

Fig 1



Temperature °A
Scale 5°A
Millibar
Scale 10 mb
Surface
15 gkm
Jan
Feb 1929

Fig 2

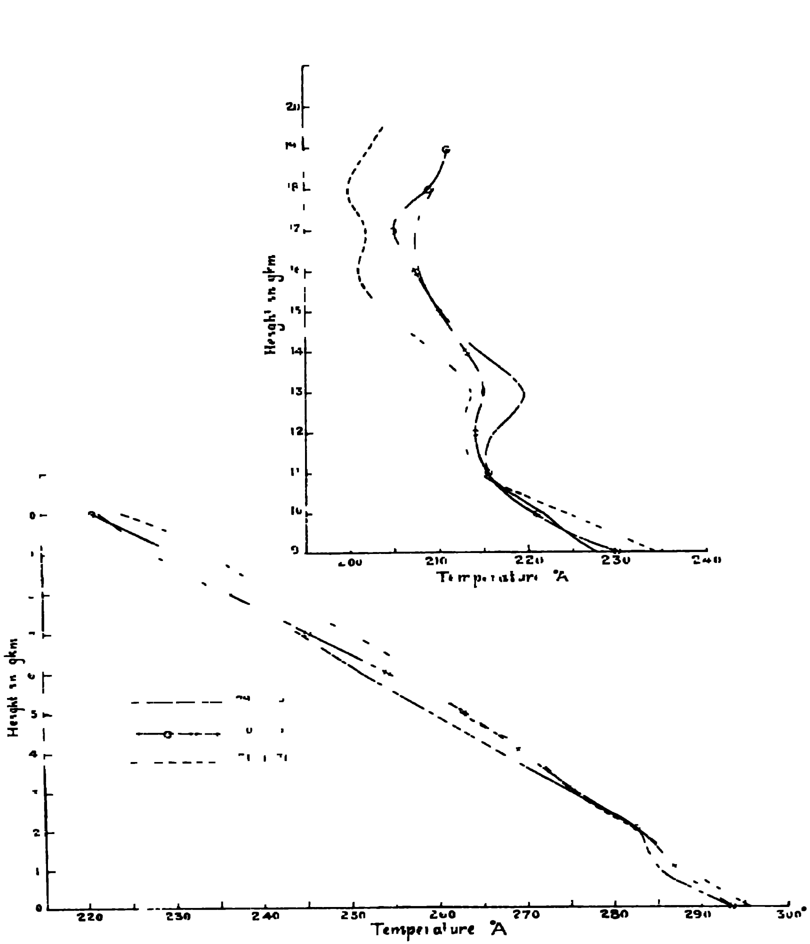

Height in gkm
Temperature °A

Fig 3

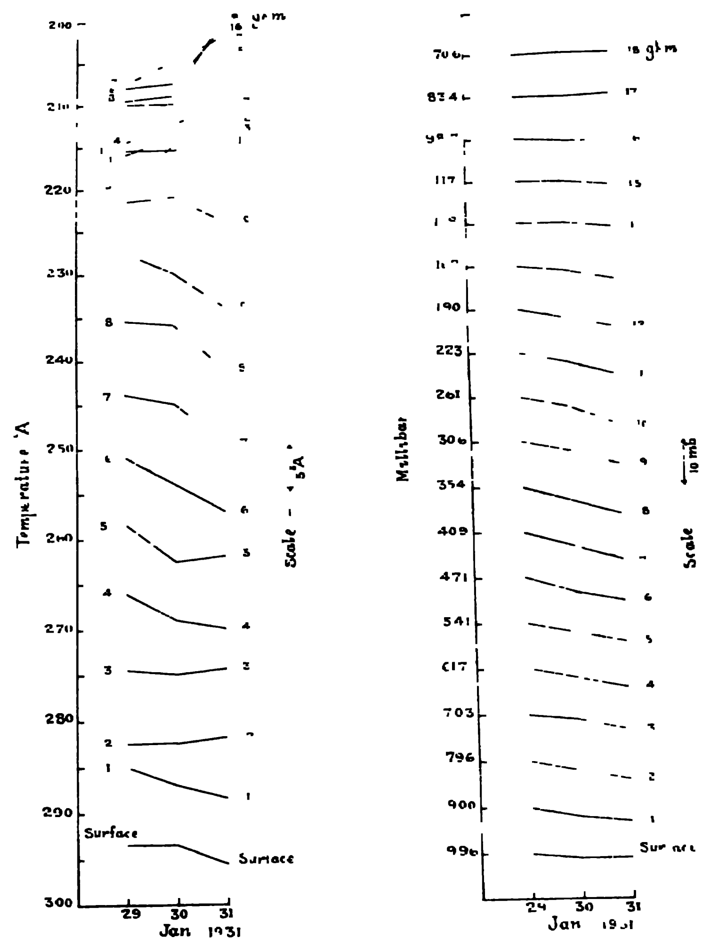

Temperature °A
Scale
Surface
Jan 1931
Millibar
Scale
10 mb
Jan 1931

Fig 4

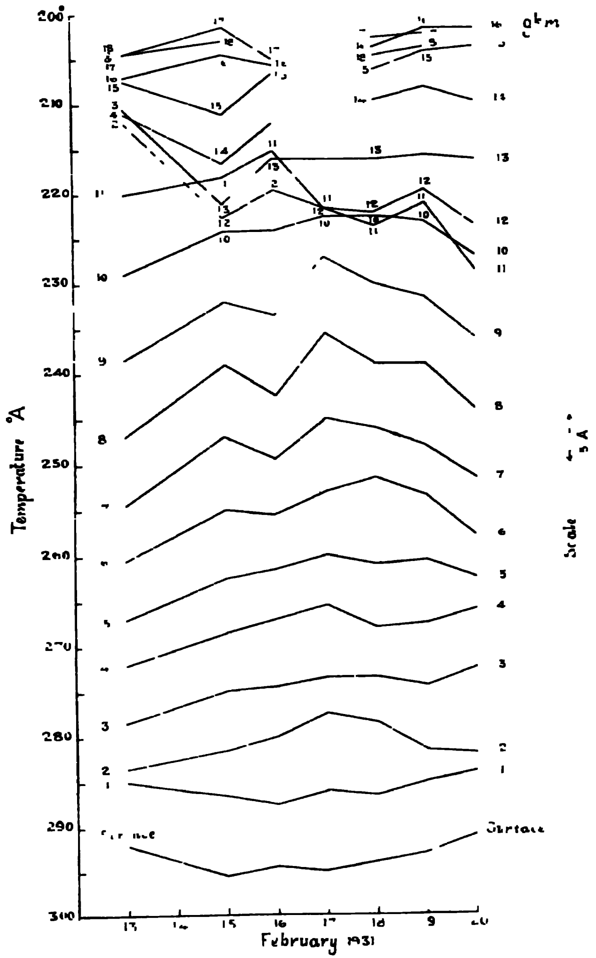

Temperature °A
February 1931
Scale
5 A
Surface

Fig 5(a)

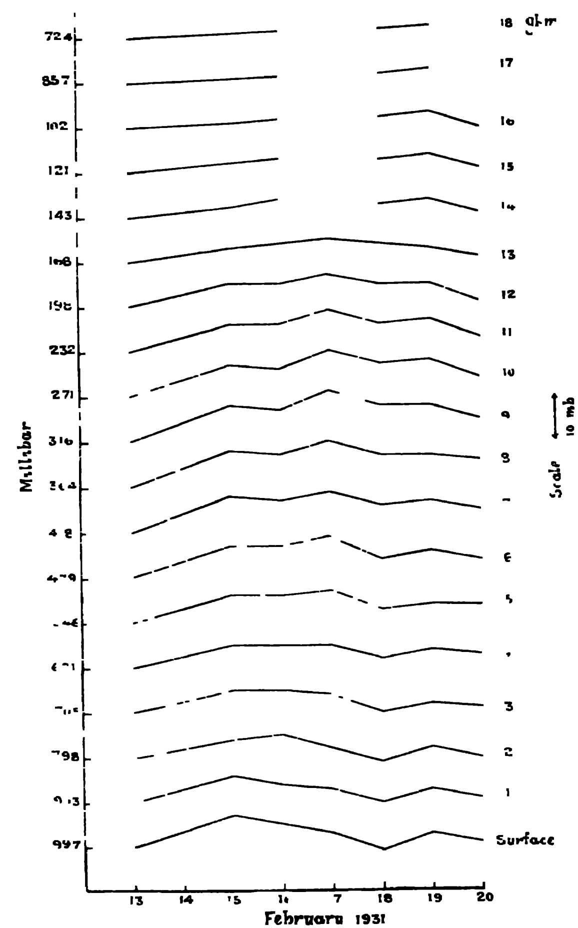
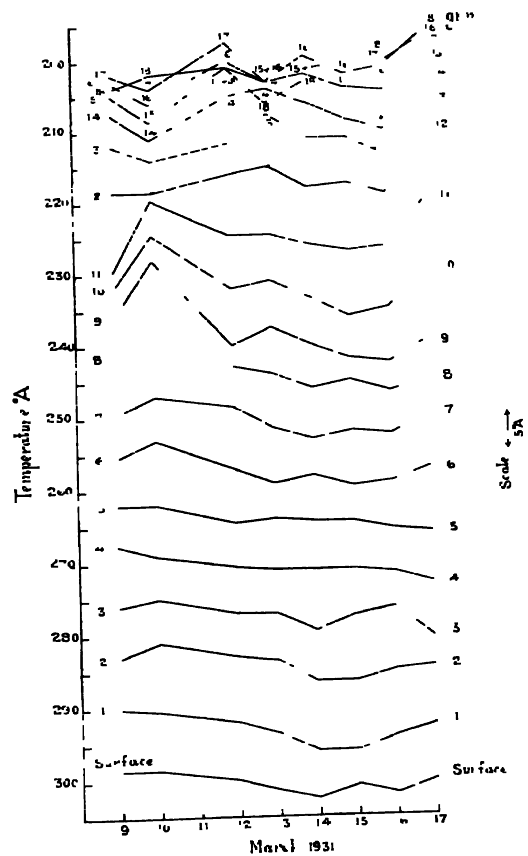
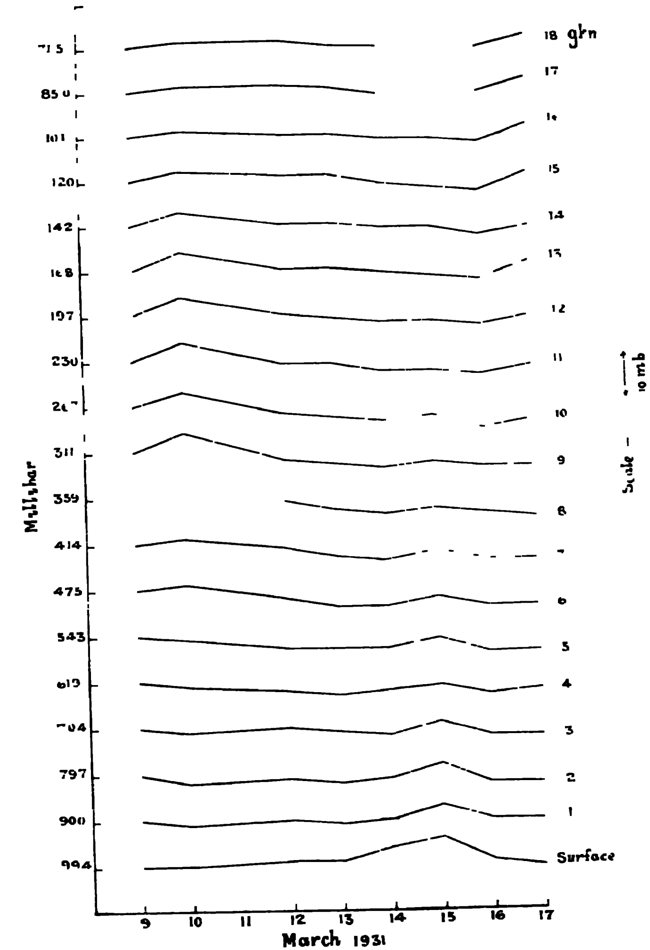

Millibar
February 1931
Scale
10 mb
Surface

Fig 5 (b)



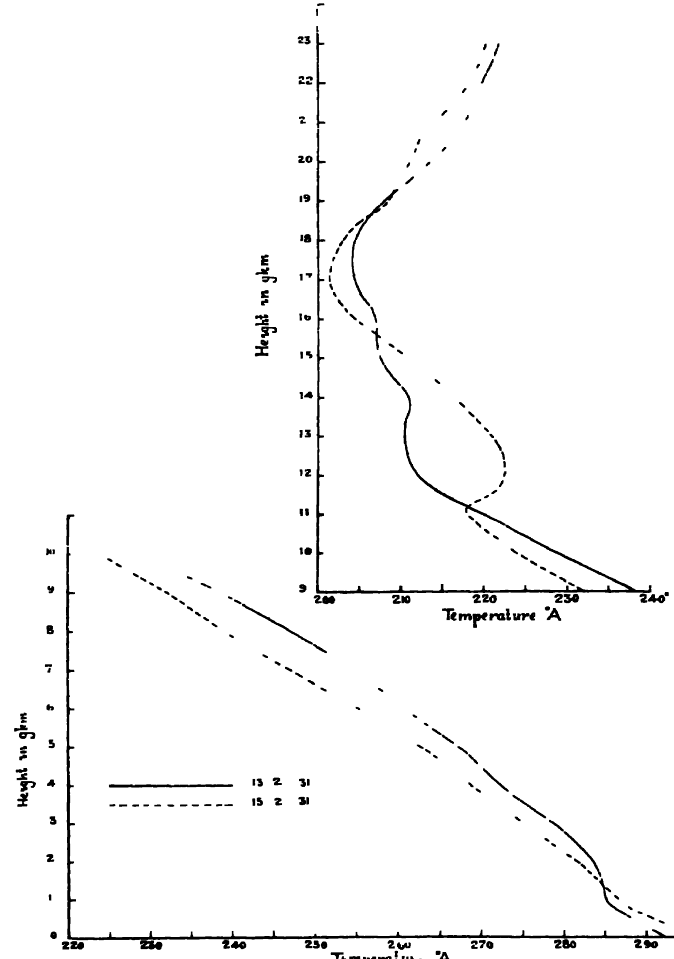
Temperature °A
Scale 5A
March 1931
Surface

Fig 6(a)



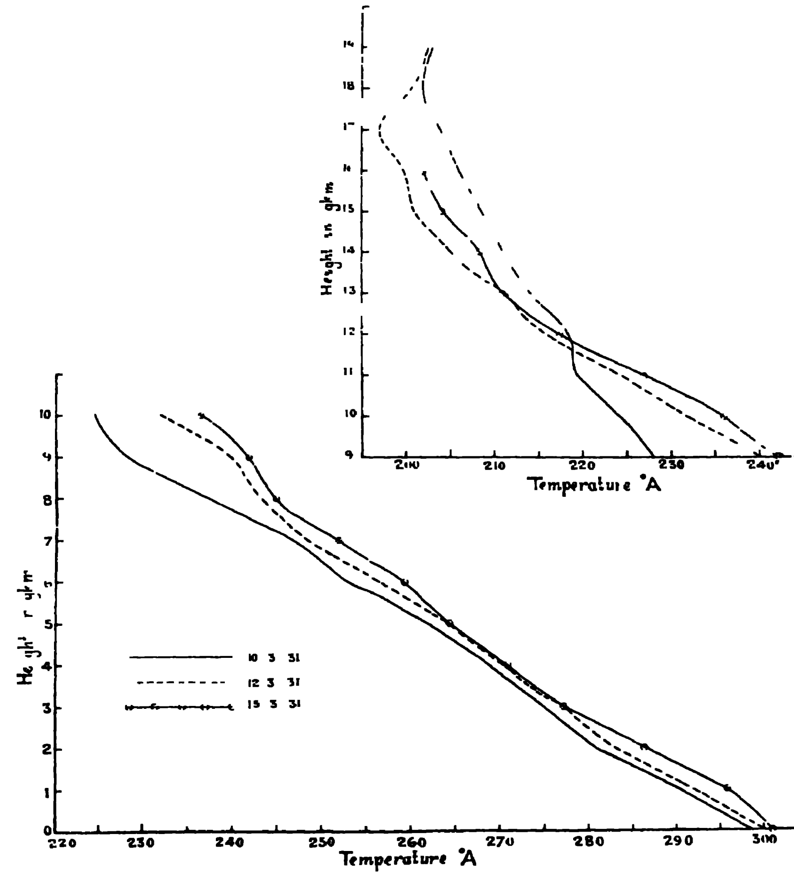
Millibar
18 gkm
Scale 10 mb
March 1931
Surface

Fig 6(b)



Height in gkm
Temperature °A
13 2 31
15 2 31

Fig 7



Height in gkm
Temperature °A
10 3 31
12 3 31
15 3 31

Fig 8

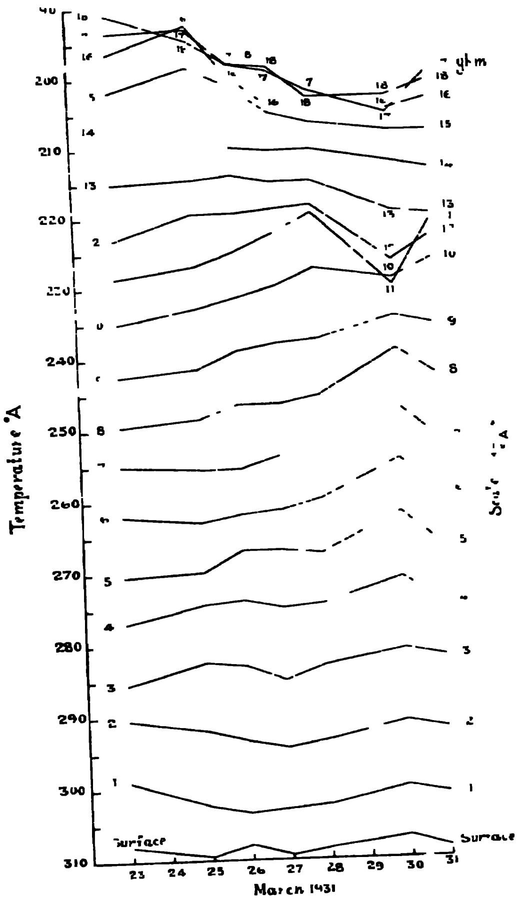

Temperature °A
March 1931
Surface
gkm

Fig 9(a)

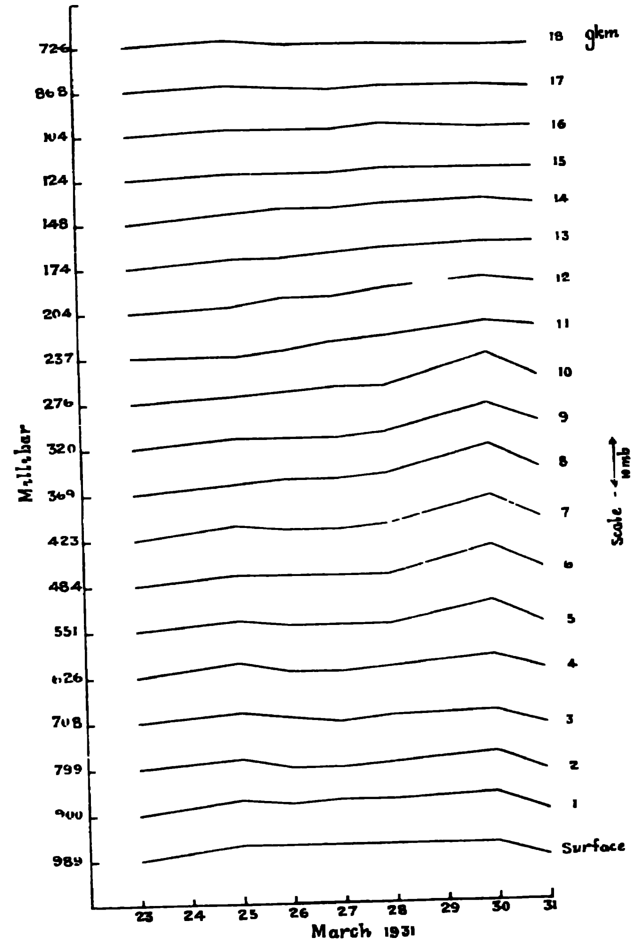

Millibar
March 1931
Surface
gkm
Scale

Fig 9(b)

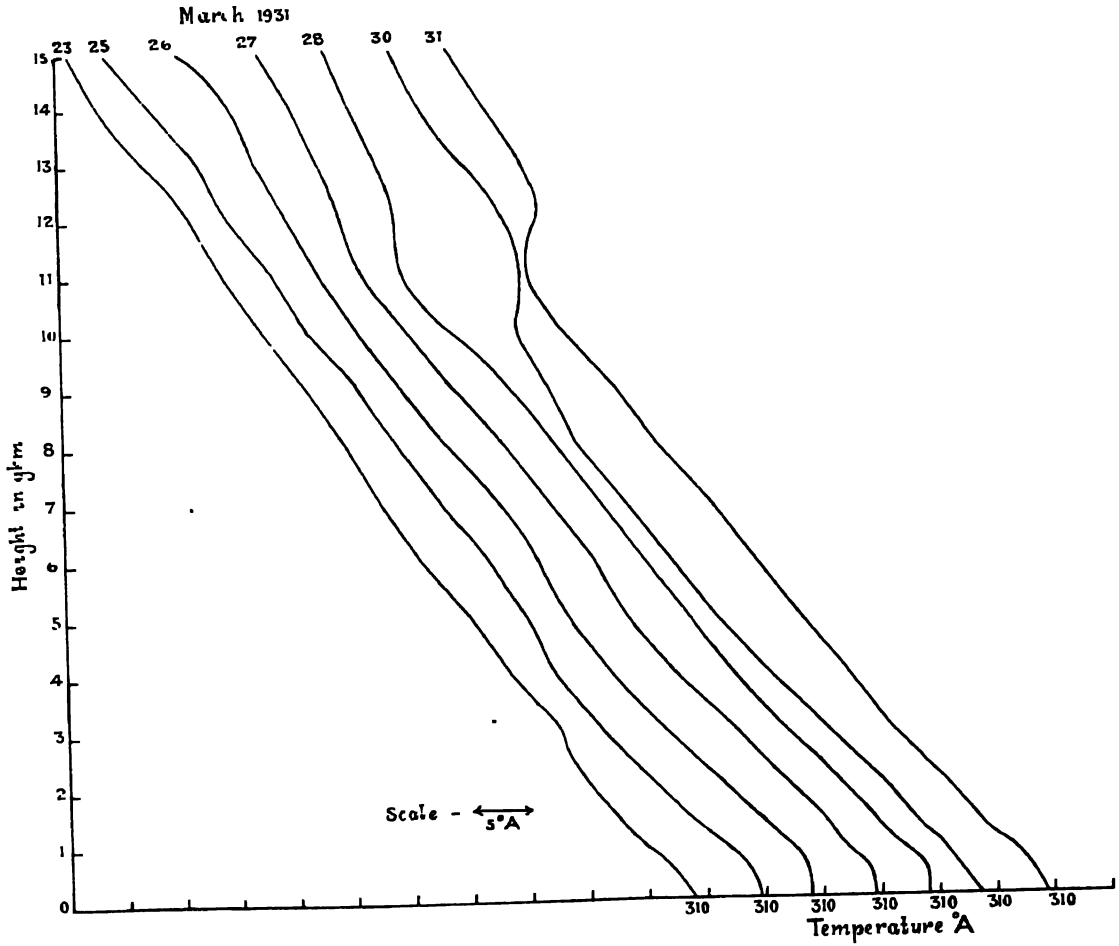

March 1931
23
25
26
27
28
30
31
Height in km
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
310
310
310
310
310
310
310
Temperature °A
Scale - 5°A

Fig. 10

DGO. 19. VII. 72.
370.

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. VII, No. 72.

Normal Monthly Percentage Frequencies of Surface and Upper Winds up to 3 km. at Allahabad, Begumpet, Delhi, Sambalpur, Sandoway, Silchar and Victoria Point.

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551·553·6 (54)
551·557 (54)

NORMAL MONTHLY PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS, UP TO 3 KM. AT ALLAHABAD, BEGUMPET, DELHI, SAMBALPUR, SANDOWAY, SILCHAR AND VICTORIA POINT.

The monthly average frequencies, expressed as percentages, of surface and upper winds up to 3 km based on observations of pilot balloon ascents made in the morning up to 10 hrs at 32 pilot balloon stations were published in 1930 in Scientific Notes, Volume, 2, No 17. The present note contains similar data for 7 more stations which were started during the years 1929 to 1932 arranged in a slightly different form.

The table below gives the names of the stations and other particulars relating to the data used in this Note.

No.	Station.	Lat (N) (deg min)	Long (E) (deg min)	Height above sea level (metres)	Period of data
1	Allahabad . .	2528	8151	111	March 1930 to December 1935
2	Begumpet (Hyderabad Deccan)	1726	7827	555	September 1929 to December 1935
3	Delhi .. .	2839	7717	210	November 1929 to February 1932
4	Sambalpur .. .	2128	8401	153	June 1930 to December 1935.
5	Sandoway . .	1828	9422	9	June 1932 to December 1935
6	Silchar . .	2450	9251	40	September 1932 to August 1935
7	Victoria Point	1001	9833	48	October 1932 to December 1935

The approximate British equivalents of the measures of height and velocity in metrical units used are given below for ready reference :—

Values in metrical measure.	*British equivalents.*
500 metres	1640 feet.
1000 ,,	3281 ,,
2000 ,,	6562 ,,
3000 ,,	9843 ,,
< 5 km. per hour	< 3 miles per hour.
6—25 ,, ,, ,,	3·5-15·5 ,, ,, ,,
26-50 ,, ,, ,,	16-31 ,, ,, ,,
51-75 ,, ,, ,,	31·5-46·5 ,, ,, ,,
> 75 ,, ,, ,,	> 47 ,, ,, ,,

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

ALLAHABAD.

Speed limits km /hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	JANUARY.										**FEBRUARY.**									
Surface.																				
6—25	136	*51*		3	6	8	1	15	12	4	130	*52*	1	5	9	2	2	15	13	2
26—50																				..
0 5* Km.																				
6—25			5	5	10	13	3	1	16	26			10	9	5	9	5	3	11	15
26—50	133	*2*	1		2	2	1		3	12	129	*7*		2	2	2		1	2	16
51—75																1				1
>75																				..
1 0 Km.																				
6—25			7	5	2	5	5	3	17	23			3	5	6	5	6	3	12	20
26—50	132	*4*			2		2	1	5	20	128	*2*	1	2	2		1	1	6	20
51—75									1							1			2	1
>75																				
2 0 Km																				
6—25			1			1	1	5	6	7			4	2	1	2	4	4	9	6
26—50	123	*0*					1	9	24	35	116	*1*					1	6	16	27
51—75									6	5									7	9
>75																				..
3 0 Km																				
6—25				1					4	2	65	*0*	2		2			3	5	5
26—50	81	*0*						5	28	28								2	42	25
51—75								2	16	10									12	3
>75								1		1									2	
	MARCH.										**APRIL.**									
Surface																				
6—25	179	*50*	1	2	3	3	3	19	16	3	153	*43*	1	2	4	1	3	21	22	3
26—50																				
0 5* Km.																				
6—25			13	6	4	7	4	4	5	20			9	5	1	5	6	5	7	19
26—50	178	*3*	3		2	1	1	2	1	21	152	*5*	7	1	1	3	1	2	5	17
51—75			1							3										3
>75																				
1 0 Km.																				
6—25			5	2	1	5	5	8	8	24			8	3	3	3	5	3	14	18
26—50	177	*3*	1	1	1	1		1	6	26	152	*3*	3		1		1		4	26
51—75								.		2								1		4
>75																				
2 0 Km.																				
6—25			1	1		1	1	5	10	12			3	2	1	2	2	5	14	11
26—50	164	*1*	1			1	1	6	23	26	133	*2*		.			1	2	19	27
51—75									5	5									2	8
>75										1										
3 0 Km.																				
6—25			1					3	6	3				.			2		12	5
26—50	109	*1*	2				1	3	31	19	84	*1*		.			1	5	35	21
51—75								3	19	8									7	8
>75														.				.	1	1

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

ALLAHABAD.

Speed limits km /hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			MAY.										**JUNE.**							
Surface.																				
6—25	164	*37*	.	7	14	4	4	9	18	7	153	*27*	1	8	20	5	5	20	7	6
26—50													.	.				1		
0 5 Km.*																				
6—25			2	2	5	10	9	5	7	14			3	2	5	11	10	5	9	3
26—50	162	*2*	8		4	2	2	1	4	15	152	*1*	1	1	8	4	1	5	10	11
51—75				1						4				.					7	4
>75																			2	.
1 0 Km.																				
6—25			4	2	2	5	9	9	14	13			1	1	7	7	5	7	13	7
26—50	164	*4*	2			1	2	2	2	24	149	*1*	1		7	1		3	11	15
51—75			1							3									6	5
>75			.															.	1	
2 0 Km.																				
6—25			2	1	1	2	1	4	14	16			2	2	8	3	1	7	10	12
26—50	140	*1*	1	1			1	2	12	31	115	*2*	5	4	5	1	.	1	10	23
51—75									2	7						.			1	4
>75																				.
3 0 Km																				
6—25			1	1	1	1		3	6	9			5	3	5	3	3	1	5	15
26—50	99	*1*			1		1		23	33	75	*3*	9	1	7	1	.	1	8	23
51—75									3	13			1		1				1	3
>75										1										.
			JULY.										**AUGUST.**							
Surface																				
6—25	163	*24*	1	8	28	2	3	15	13	5	161	*33*	1	7	16	3		24	14	3
26—50								1							1				.	.
0 5 Km *																				
6—25			4	4	9	11	2	9	6	8			4	2	4	9	7	4	16	5
26—50	157	*3*			11	4		1	14	3	141	*2*		1	7	6	1	1	22	2
51—75					3	1	1		7	1				1	2			1	3	
>75																				
1 0 Km.																				
6—25			5	3	11	9	3	5	8	7			3	6	11	11	2	3	15	7
26—50	133	*2*	1	1	10	3		1	14	8	123	*2*		1	6	2	1	2	19	4
51—75					2		1		7	2					1				3	1
>75																				.
2 0 Km																				
6—25			11	3	12	5	2	1	7	12			6	9	13	5	5	3	16	15
26—50	94	*1*	2	1	16	2		1	4	9	80	*3*		4	9	1		.	8	3
51—75					3				4	3									3	..
>75																				.
3 0 Km.																				
6—25			7	11	11	7	2	2	7	9			7	4	16	4	13	7	16	9
26—50	46	*0*	2	2	15	4		2	.	15	56	*9*		5	4	4			2	2
51—75					2				2							.		.		.
>75																				

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

ALLAHABAD.

Speed limits km /hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
				SEPTEMBER										**OCTOBER.**						
										Surface										
6—25	158	*36*		6	20	3	1	15	13	4	175	*48*		5	5	1	2	22	16	1
26—50				1	1				.				.	.		.		.	.	
										0 5 Km *										
6—25			5	4	12	8	4	6	7	5			7	7	10	7	5	5	13	21
26—50	142	*6*		1	8	6	4	1	12	8	167	*5*	1	1	5				5	9
51—75				1	1	2			1	1									.	..
>75																				
										1 0 Km										
6—25			3	6	12	5	5	4	12	6			10	5	9	3	3	2	10	32
26—50	127	*6*	1	2	9	3		1	6	16	164	*6*	1		3	1			3	12
51—75					2	2	1									1			.	.
>75																			..	.
										2 0 Km										
6—25			4	11	11	3	5	2	6	5			15	7	1	2	3	3	6	19
26—50	114	*6*	5	2	11	5	3	1	2	15	159	*1*	3		3	1			8	26
51—75					1	3				1										2
>75									.											.
										3 0 Km										
6—25			6	6	16	5	5	3	13				6	4	4	2	3	7	13	18
26—50	77	*1*	3	3	8	9	1	4	1	10	136	*1*	3			1	1	4	7	23
51—75			1		1	3		.											1	2
>75																			.	.
				NOVEMBER										**DECEMBER.**						
										Surface.										
6—25	160	*52*	.	2	1	1	1	18	24	1	168	*54*	1	3	5	4	1	12	18	2
26—50			.	.		.												.		..
										0 5 Km *										
6—25			5	8	8	4	1	2	17	34			11	9	7	10	2	3	7	30
26—50	157	*6*	.						3	11	168	*9*			.	2		1	1	7
51—75																.		1	..	1
>75																		.		..
										1 0 Km										
6—25			10	7	8	1		1	5	38			10	7	5	6	1	3	15	30
26—50	157	*3*		.				.	1	27	168	*4*		..	.	.	1	..	2	15
51—75														.	.	.		1	.	1
>75													..	.						
										2 0 Km										
6—25			8	2	2	1	1	1	5	15			4	1	1	3	1	3	10	17
26—50	154	*3*	6					1	6	42	160	*1*	1					3	16	38
51—75										9			1						1	2
>75																				
										3 0 Km.										
6—25			2	2	1	1	1	4	4	16			2				1	2	7	8
26—50	122	*0*	7					2	17	37	126	*0*	2					2	32	30
51—75										6								2	5	6
>75																			1	1

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

BEGUMPET.

Speed limits km /hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			JANUARY.										FEBRUARY.							
Surface.																				
6—25	170	*80*		1	6	9	.	1	1	2	156	*69*	1	2	6	12	1	3	1	7
26—50					.	.		.		..			.	.	.	.		..	..	..
0 5 Km *																				
6—25				7	34	17	6	2	1				.	10	11	16	12	7	3	1
26—50	164	*1*		1	7	21	2	1			154	*1*	3	3	3	14	6	8	1	2
51—75				.	.	1							.			.	1	.	.	.
>75										.			.		.		.		.	..
1 0 Km																				
6—25			.	7	20	15	7	2	7	..			.	14	20	18	12	8	8	..
26—50	46	*2*	.	.	2	37	2		.		50	*0*	4	2	2	4	2	4	.	2
51—75				.						50			.	.	.	.	..		..	.
>75				.	..	.	.	.	.	..			.	..	.	..		.	.	.
2 0 Km.																				
6—25			11	16	16	11	2	4	9	6			14	7	5	3	8	11	16	16
26—50	159	*4*	3	8	3	1	1	3	1	3	152	*1*	4	5	.	1	1	5	3	1
51—75			.			.			.					..	.	.	.	.	..	..
>75				.					.							.		.	..	.
3 0 Km.																				
6—25			9	11	8	5	8	10	9	8			15	3	2	3	3	9	10	16
26—50	157	*6*	3	4	3	1		3	8	4	149	*1*	9	3	..	..	1	8	5	7
51—75									.	1			..	.	..	.		1	3	1
>75			.	.			.		.	.			..	.	..			.	..	..
			MARCH.										APRIL							
Surface																				
6—25	185	*76*	2	1	4	9	1	2	3	3	176	*51*	2	1	8	8	3	6	7	14
26—50				..		.	.		.						1		..	.	.	.
0 5 Km.*																				
6—25			3	4	9	17	15	8	3	2			2	2	1	8	13	6	10	2
26—50	184	*1*	2	1	1	15	7	12	2	.	173	*0*	8	2	1	8	9	14	5	5
51—75						1	1						2				1	1	.	1
>75				.		.								..						
1 0 Km.																				
6—25			5	2	8	23	11	5	3	3			3	2	..	3	10	8	8	2
26—50	62	*0*	2	2	3	11	10	8	3		60	*0*	13	5	2	3	7	18	10	3
51—75					.	2	.			.					.		.	..	..	2
>75														..	..	.		..	..	..
2 0 Km.																				
6—25			7	12	14	9	8	9	3	7			9	14	8	13	13	9	8	8
26—50	182	*3*	2	9	4	3	4	3	2		173	*2*	1	2	2	2	3	2	1	3
51—75				.	.		.		.				.	.		..	..	.	.	.
>75					.	.	.		.	.				.	.	..	..	..	..	..
3 0 Km.																				
6—25			17	14	7	7	2	9	7	10			11	28	12	4	5	8	9	6
26—50	179	*6*	9	3	.	1	1	1	2	3	169	*3*	7	6	1	.	..	..	1	..
51—76			1	.	..	..				.			.	..	.	..	..	..	..	1
>75				..		.								.	.	.	..	..	..	.

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS

BEGUMPET.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	MAY.										**JUNE.**									
										Surface										
6—25	178	*33*	1	..	6	3	1	7	26	22	164	*2*	..		.		1	7	68	19
26—50				..	.	..	..	1		1			.	..	.	.		.	2	..
										0 5 Km.*										
6—25			5	1	.	2	3	8	7	6					..	1	1	.	3	1
26—50	175	*1*	9		1	3	2	13	11	16	159	*0*	1		..		.	2	37	28
51—75			6		1	1		.		7			.	.	..		.	..	18	8
>75			.	..			.						.	.	..		..	..	1	.
										1 0 Km.										
6—25			5		.	2		5	7	7			.						2	2
26—50	59	*0*	15		2		2	10	14	14	54	*0*	2					9	48	19
51—75			.						2	5								2	13	2
>75														.	.			.	2	.
										2 0 Km										
6—25			11	6	7	6	11	10	7	8			8	1	3	1		6	13	19
26—50	175	*1*	16	2	2	1	1	3	3	5	139	*0*	5				1	4	12	14
51—75													1					.	6	2
>75																		1	1	1
										3 0 Km										
6—25			17	24	14	8	1	3	5	8			7	7	7	5	10	10	11	9
26—50	178	*2*	4	8	2		.	.	1	1	120	*10*	3	3	1	2		3	6	3
51—75			1	1	.	.	.			1			2		.			..	3	.
>75					.	.	.								.			.	1	.
	JULY.										**AUGUST.**									
										Surface										
6—25	175	*2*	.		..	..	..	10	72	7	173	*16*		.	1	3	1	6	58	13
26—50			.	.	..	..		1	8				.		.		.	.	3	..
										0 5 Km*										
6—25	•				..		1	1	3	1			1	1		5	3	2	4	
26—50	164	*0*	1						20	18	156	*1*	1	.	1	3		1	18	20
51—75			.	.					45	7							.		34	3
>75			.	.	.		.		5					.			.		1	..
										1 0 Km.										
6—25					.				8					.		6	3	3	8	3
26—50	58	*0*		..		.	.	.	21	15	78	*0*	1			3		1	19	21
51—75				.			.		45	4					.	..	.	.	31	3
>75			..	.			.	..	8	.					.	.	.		..	..
										2 0 Km.										
6—25			3				1	2	7	4			4	4	4	3	1	5	12	11
26—50	118	*1*		.	.			1	26	15	118	*3*	1	..	.	..	.	1	19	10
51—75			..	.	..	..			24	10				.		..	.	.	15	4
>75			..		.	.		.	5	2					..	..	..	..	1	..
										3 0 Km.										
6—25			3		..	.	1	13	15	13			4	4	8	2	2	9	20	11
26—50	67	*1*	.		.	.	.	3	30	6	85	*7*		.	..	..	..	4	21	4
51—75			.	.		..		..	9	1			.	..	..	..	..	..	4	1
>75			..	..	..	..	.	..	1	..			..	..	..	..	..	..	..	..

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

BEGUMPET.

Speed limits km /hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
				SEPTEMBER.											OCTOBER.					
										Surface.										
6—25	176	*21*	1			1	.	5	41	28	190	*73*	4	1	3	3	.	4	7	5
26—50							.		3	1					.	.	..	..	..	..
										0 5 Km.*										
6—25			4	5	3	6	2	2	6	8			6	15	26	11	3	1	2	3
26—50	157	*0*	1	1				1	13	31	185	*1*	3	8	10	2	.	1	8	2
51—75								1	10	8					1	.	.		2	1
>75							.									..		.	.	.
										1 0 Km										
6—25			1	4	1	7	1	4	7	6			6	21	28	1	1			
26—50	71	*0*						1	7	31	85	*0*	4	9	11	2			2	1
51 - 75								1	16	11					1				2	.
>75																				.
										2 0 Km.										
6—25			9	10	6	2	2	2	5	12			12	23	22	4	1	1	3	5
26—50	130	*3*		3	1			2	21	15	169	*1*	5	8	6			2	2	3
51—75									2	4				1	1					.
>75																				
										3 0 Km										
6—25			10	7	10	4	1	5	15	16			9	27	20	4	2	3	4	10
26—30	102	*2*	*3*	7					8	14	162	*1*	*2*	7	4			2	1	1
51—75														1						
>75																	.		..	
				NOVEMBER										DECEMBER.						
										Surface										
6—25	186	*81*	5	3	4	5	..			3	193	*83*	3	2	2	9			..	2
26—50			.	.						..									.	..
										0 5 Km *										
6—25			5	24	29	12	1		1				2	12	35	23	5	●	1	1
26—30	180	*1*	2	15	8	2					188	*1*		4	7	7	1	1		.
51—75				1		.								1		1				
>75																				
										1 0 Km										
6—25			6	36	29	9	1						2	7	28	31	5			
26—50	77	*0*	1	13	.		3				83	*1*		4	7	13	1	.		.
51—75				1	.															..
>75			.	.	.	.							.						.	.
										2 0 Km.										
6—25			12	24	15	4	4	1	2	5			11	21	17	5	4	2	4	10
26—50	163	*4*	4	18	8	1		..			183	*5*	4	8	6			1		.
51—75			.	.						.				1	1				..	..
>75			.	..									.			.			.	..
										3 0 Km										
6—25			12	26	24	7	4	2	3	1			11	14	15	6	5	3	8	11
26—50	156	*4*	3	8	6		.	.		1	177	*7*	5	3	7			2	4	1
51—75			.	.	..	..	..	..								..	..	.	..	..
>75			..	..	..	..	..		.	.				.	..	.		..	..	..

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

DELHI.

Speed limits km /hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			JANUARY.										FEBRUARY							
Surface.																				
6—25	60	*57*			2	3	..	3	20	15	56	*66*	..	.	2	4	..	2	7	20
26—50							.			.			..				.	..	..	..
0 5 Km *																				
6—25			10		2	3		3	5	34			5	4	4	7	11	2	16	13
26—50	59	*3*				3	3		2	31	56	*5*	2			.	5	.	.	25
51—75																2		..	..	..
>75													.			.		..	..	..
1 0 Km																				
6—25			2	2	3		3	3	17	29			7		2	7	14	5	11	18
26—50	59	*2*		.		2	2		2	32	56	*2*					5	2	2	20
51—75			.		.												2		.	..
>75					.														..	..
2 0 Km																				
6—25				2			9	12	18	21			7		4	2	6	15	17	9
26—50	57	*2*	2				5		12	18	53	*0*				2		4	13	19
51—75																		.		2
>75																	.		..	.
3 0 Km																				
6—25							4	6	13	2						2	2	9	9	9
26—50	48	*0*						13	39	15	44	*0*						16	25	20
51—75								2	2	4								2	2	2
>75									.									.	..	

Speed limits km /hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			MARCH										APRIL.							
Surface																				
6—25	62	*51*	.		5	2		3	23	16	60	*50*	2	2	..	3		2	28	13
26—50				.	.			.									.		.	.
0 5 Km *																				
6—25			8	2	2	6	6		4	16			10	2	2	5	3	5	3	9
26—50	62	*5*	6	2	2	2				29	58	*5*	3			2		.	2	40
51—75										6						2		.	2	5
>75										2									..	.
1 0 Km.																				
6—25			5	5	2	5	2	5	8	18			15		2	3	2	8	7	15
26—50	62	*5*					2	.		34	59	*3*							3	35
51—75			.		.				2	8						2			2	2
>75			..		.			.		2						.				
2 0 Km																				
6—25			2		2		2	8	7	18			2	2	2		2	7	16	15
26—50	60	*2*					..	3	12	28	55	*2*	.			.	2		13	21
51—75									2	13										16
>75					.		.	.		2									.	..
3 0 Km																				
6—25								7	11	15					2		2	13	2	20
26—50	53	*0*		..				2	17	23	46	*0*					4	2	20	22
51—75			.					.	9	9								..	2	7
>75					.				.	2										4

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km /hr or less.

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M20DGofOb.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS

DELHI.

Speed limits km /hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			MAY.										JUNE.							
										Surface.										
6—25	62	*49*	2	3	3	6	.	6	23	8	60	*43*	3		13	8	.	3	20	8
26—50				.		.	.						.				.			.
										0 5 Km.*										
6—25			8	5	2	6	5		11	15			3	7	2	10	5	2	2	3
26—50	62	*2*	3	.		8	2		13	15	60	*0*	3	2		12	5	2	5	23
51—75				2					3	2									5	8
>75						.										.		..	2	
										1 0 Km										
6—25			3		7	7	2	7	8	20			5	3	3	9	7	2	2	12
26—50	61	*3*	.			3	2		10	18	58	*2*	3		2	10	2		5	19
51—75					2				3	7					.			.	2	9
> 75				..															3	
										2 0 Km										
6—25			7	3	2		2	9	12	10			6	2	6	2	6		14	16
26—50	58	*5*							14	26	50	*0*	6		2	2			6	26
51—75										10									2	4
>75																			.	
										3 0 Km.										
6—25			2	2	2		2	7	11	2			14	3	3	10		7	7	17
26—50	46	*4*						2	15	24	29	*0*	3		3				7	17
51—75									2	20										7
>75								.		2										.
			JULY.										AUGUST							
										Surface										
6—25	61	*57*	3	3	10	11		3	11	.	62	*42*		3	18	6		6	18	6
26—50				.		.												.	.	
										0 5 Km.*										
6—25			5	3	7	9	5	3	15	5				2	7	19	3	7	3	2
26—50	58	*5*		.	3	10		2	14	5	59	*7*			3	13	.		12	
51—75						3			2							2			17	3
>75			.	.		.			2										.	
										1 0 Km.										
6—25			4	2	13	7	4	5	11	13			3	2	9	14	3	9	7	
26—50	56	*4*			2	9		2	9	5	58	*3*			5	14	2	.	10	12
51—75					2	4			4								1	.	3	3
>75			.			.	.		4							.		..	.	..
										2·0 Km										
6—25			9	5	11	5	7	2	5	18			16	6	12	16	4	.	4	16
26—50	44	*2*	2		2	5		2	5	14	51	*2*		4	14			.	..	8
51—75					5	2							.		.				..	..
>75				.											.	.	.	.	..	.
										3 0 Km.										
6—25			11	15	15		4	4	4	11			6	6	12	18	9	..	6	..
26—50	27	*4*	4	.		11			4	11	33	*18*	3	3	6	3	..	..	.	6
51—75				.	4		.	.		.			.		3	.	.	.	..	..
>75					.			.	.				..	.	.	..	.	..	..	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km /hr or less.

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

DELHI.

Speed limits km /hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			SEPTEMBER.										**OCTOBER.**							
Surface																				
6—25	60	*62*	5	3	3	5	2	8	12	.	62	*90*	.	2		3			3	2
26—50					.			..		.			.	.				..	..	..
0 5 Km.*																				
6—25			10	5	2	3	9	7	9	12			10	5	3	21	11	6	8	13
26—50	58	*9*	2		7	3	2	..	7	5	62	*6*	2			10	.	..	2	3
51—75									7	2					.				..	..
>75							..	.					.		..	..		.	..	..
1 0 Km.																				
6—25			9	2		11	2	3	5	16			13	5	6	19	10	5	5	21
26—50	56	*7*	5		5	3	2		7	16	62	*5*			2	5	.	.	2	3
51—75						2			.	3								.	.	..
>75									.								..	.	.	..
2 0 Km.																				
6—25			20	10	2	6			2	22			7	..	14	3	3	7	7	14
26—50	50	*0*	8	2						24	58	*7*	.	2	3			2	5	24
51—75									2	2			.		2			.	..	..
>75														.					..	..
3 0 Km.																				
6—26			14	14	9	6			6	26				11	11	4	2	13	11	11
26—50	35	*3*	11	3		3				6	47	*0*	6	2	2	.	2	.	2	23
51—75										.						.		..	..	..
>75																.		..	.	..
			NOVEMBER										**DECEMBER.**							
Surface																				
6—25	59	*73*						5	22		92	*62*		2	1	4		1	21	10
26—50															.	.			..	..
0 5 Km.*																				
6—25			12	5	3	3		6	11	20			5	2	3	4	5	2	1	31
26—50	66	*18*								21	90	*9*		1	.	3	1	.	..	24
51—75										1								.	.	5
>75																		.	..	..
1 0 Km.																				
6—25			12	5	5	1			17	30			4	2	1	3	1	3	6	33
26—50	66	*5*	..						1	23	90	*8*	1	..	1	2		1	1	22
51—75										1			..	.	.			..	..	8
>75														..	.				.	.
2 0 Km.																				
6—25			6		1	5	1		6	24			5	1	.		2	6	17	30
26—50	66	*0*	6			1			7	30	86	*0*					1	2	2	28
51—75						.				1								.	..	5
>75																.		..	..	..
3 0 Km.																				
6—25			4			4		2	10	37			3	1	.	1	1	7	22	12
26—50	52	*2*				.			10	21	74	*3*	3		..	..	..	7	22	15
51—75										2				.	..	..	..	..	1	3
>75													.		..	..	.	..	..	..

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SAMBALPUR.

Speed limits km/hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
				JANUARY											FEBRUARY.					
										Surface										
6—25	144	94	1	1	1	1				1	125	89	2	4	2	2				2
26—50																				.
										0 5 Km *										
6—25			16	7	11	10	7	10	10	11			15	10	8	10	13	9	9	7
26—50	140	12	2			1		2	1		124	4	2	2		2	1	5	1	1
51—75																				
>75																				
										1 0 Km										
6—25			21	4	5	7	4	6	15	21			15	3	1	5	9	11	9	18
26—50	140	5				1	1	2	1	3	123	4	2	1		1	2	6	7	6
51—75																			1	
>75																				
										2 0 Km.										
6—25			11	6		1	1	6	9	18			1		1		1	10	11	14
26—50	139	3	10	1			1	1	9	19	124	1	3			1		4	27	23
51—75									1	1										2
>75																				
										3 0 Km										
6—25			5	1		1	2	4	8	18			2				1	1	3	8
26—50	124	2						3	12	31	111	1						1	31	25
51—75								1	4	2								4	10	9
>75									1										1	1
				MARCH											APRIL					
										Surface.										
6—25	186	56	3	5		1				4	131	89	3	2		2		2	2	1
26—50			1																	.
										0 5 Km *										
6—25			9	18	4	7	9	20	8	5			11	6	4	7	9	21	9	5
26—50	182	4	4	4	2	2		7			129	2	2	2			1	14	5	1
51—75													1					1		
>75																				
										1 0 Km										
6—25			15	7	3	5	9	10	15	10			8	6	2	3	9	15	11	9
26—50	185	4	7	1	1	1		8	1	2	129	2	5	2	1		1	12	10	2
51—75													1					1	2	
>75																			.	
										2 0 Km.										
6—25			13	1	2	1	5	10	24	13			9	3	1	1	2	8	18	22
26—50	185	1	1	1		1		3	11	11	129	5						3	16	12
51—75										1								1	2	
>75																	.			
										3 0 Km.										
6—25			9	1		1		3	15	13			4	1	1	1		7	9	23
26—50	121	1	6	1		1		2	26	20	112	0	1			.		3	27	21
51—75									2	1									3	
>75																.	..		.	

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C represents the percentage number of cases when speed was 5 km./hr or less,

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SAMBALPUR.

Speed limits km./hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
					MAY.										JUNE.					
Surface																				
6—25	142	*76*	1	4	4	8		6	1	1	142	*62*	1	1	2	4	4	20	4	3
26—50										.			.						..	..
0 5 Km *																				
6—25			4	4	4	6	15	21	6	3			1	4	3	2	13	19	10	8
26—50	140	*1*	3	1		1	2	25	1	3	136	*0*	1	1			1	16	21	1
51—75																			.	.
>75																			.	..
1 0 Km																				
6—25			7	4	3	5	7	15	9	4			5	2	2		5	12	12	8
26—50	141	*1*	6	2				19	10	6	130	*0*	1	2	2			12	30	2
51—75								2											5	1
>75																			.	.
2 0 Km																				
6—25			7	4	2	2	1	4	18	18			7	4	2		3	6	10	15
26—50	141	*4*	9	1				1	9	14	111	*1*	5	1	1			4	23	14
51—75									3	1									2	3
>75										..									.	1
3 0 Km																				
6—25			6	2	2	2	1	1	6	22			15	3	3	1	4	5	10	13
26—50	124	*3*	6		1			1	15	27	91	*1*	8	2				2	8	20
51—75			2	1					2	1					1				..	2
>75										1									..	
					JULY.										AUGUST.					
Surface																				
6—25	168	*53*	2	1		1	3	30	7	2	169	*49*	1	1		1	2	40	5	1
26—50																			..	..
0 5 Km *																				
6—25			1	1	5	3	7	8	17	4			1	3	1	3	4	10	19	4
26—50	117	*3*		3				14	28	2	144	*3*		1	1		1	17	28	..
51—75								2	3									1	1	.
>75								1									.		..	
1 0 Km																				
6—25			2	5	8	2	2	8	6	4			4	4	2	2	3	9	11	6
26—50	102	*4*	2	2				8	27	6	117	*1*		1	3		1	7	28	7
51—75								1	15	2				1				3	8	
2 0 Km.																				
6—25			2	4	11	2	2	5	14	4			7	1	7	4	3	7	14	6
26—50	57	*4*		2	4				26	9	70	*3*	1	1	4			9	20	7
51—75									7	5				1					3	..
>75									2										..	
3 0 Km.																				
6—25				11	8	6	6	11	6	22			5	7	10	2	10	2	17	14
26—50	36	*3*	3		8				8	3	42	*0*		2	5	2		10	12	2
51—75									3										..	..
>75								.	3						.			.	..	..

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SAMBALPUR.

Speed limits km /hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	SEPTEMBER.										**OCTOBER.**									
	Surface.																			
6—25	**164**	*66*	1	5	1	2	2	18	3	1	**169**	*86*	5	4	1			2		3
26—50							.		.										.	
	0 5 Km.*																			
6—25			5	6	7	10	3	9	11	11			7	19	19	6	3	4	8	6
26—50	**147**	*5*		2	5	1	2	11	8	4	**162**	*10*	1	9	2	1	1	1	1	1
51—75															1	1		.		
>75						.								.						
	1 0 Km.																			
6—25			9	7	8	7	5	7	8	12			19	16	20	3	2	2	4	7
26—50	**130**	*1*	2	2	5	2		6	12	5	**161**	*5*	2	7	3	2	1	1	2	1
51—75					1	.		.	1						1	1				
>75						.			.											
	2 0 Km.																			
6—25			12	7	16	4	1	4	10	7			16	16	14	4	3	5	8	7
26—50	**102**	*3*	5	2	8	3		2	9	6	**153**	*7*	6	5	3		1	1	3	1
51—75					2	.			1	.										.
>75						.														
	3 0 Km.																			
6—25			5	12	11	8	3	2	8	3			10	14	10	6	4	13	9	9
26—50	**66**	*6*	5	5	9	2	2	5	11	5	**125**	*10*	6	1	1		1	3	2	2
51—75			2			2							1							
>75																				
	NOVEMBER.										**DECEMBER.**									
	Surface.																			
6—25	**168**	*85*	7	2	1			1		5	**178**	*95*	2	1						2
26—50						.														
	0 5 Km.*																			
6—25			20	28	12	4	3	2	6	8			15	20	16	11	9	2	3	9
26—50	**162**	*6*	1	9	1	1					**172**	*13*	1	1			.	1		
51—75																.				
>75									.											
	1 0 Km.																			
6—25			26	22	10	3	1		6	11			25	18	11	4	5	5	3	12
26—50	**159**	*6*	7	4	2		1		..	1	**173**	*13*	2	1				1	1	1
51—75				1									.							
>75																				
	2 0 Km.																			
6—25			22	8	3	2	3	3	7	20			21	6	2	1	2	5	11	17
26—50	**156**	*4*	16	1	1	1	1		3	6	**169**	*1*	14					1	6	14
51—75			.		1								1							.
>75																				
	3 0 Km.																			
6—25			13	4	4	4	3	2	14	22			9	1	.	1	2	5	14	15
26—50	**136**	*4*	6	1	1	1	1	1	4	13	**150**	*1*	7	1		.	.	2	11	23
51—75								1	..	1			3	..	.	.		.	2	3
>75										.			.	..		.	..	.		

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr. or less.

*0·5 km. is above surface, all other heights are above m.s.l.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SANDOWAY.

Speed limits km /hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			JANUARY											FEBRUARY.						
Surface.																				
6—25	93	98			2						84	100		.		.	.	..		.
26—50																..	.	..	..	.
0 5 Km.*																				
6—25			27	5	16	3	6	3	1	12			38	6	7	2	10	6	6	14
26—50	93	22	2		1	.				1	84	5	5			.	.		..	1
51—75																.			..	..
>75																.	.			..
1 0 Km.																				
6—25			13	4	4	10	15	13	12	14			10	4	2	8	2	11	11	19
26—50	93	5	4							5	84	2	10		1		2	2	5	11
51—75																	..		.	.
>75																		.	.	
2 0 Km																				
6—25			10	2	3	1	12	17	24	8			10	2		5	6	10	7	14
26—50	98	4	2	1		.	3	5	6	1	83	5	5			2	4	11	10	10
51—75					.	.	..						.							.
>75																				
3 0 Km																				
6—25			3	2	2	1		16	26	5			4					18	18	17
26—50	87	1		1			1	8	21	10	78	1				.	3	10	21	13
51—75																	1	1	1	1
>75										1									.	.
			MARCH.											APRIL.						
Surface.																				
6—25	93	99		.	1			.			90	98			.	2		..	..	..
26—50			.							.							.		.	.
0 5 Km.*																				
6—25			42	2	.	2		1	3	30			31	.	2			8	9	38
26—50	93	14	2								86	12	3		.		..	.	..	.
51—75			.						.								.		..	..
>75			.													.	.	..	..	..
1 0 Km.																				
6—25			16	4	1	1	3	6	10	27			11	1				5	23	39
26—50	89	1	10				1	2	2	15	83	1	2		1		.		..	17
51—75									.	.						.	.		.	.
>75				.	.	.		..	.						..	.	..	.	..	..
2 0 Km.																				
6—25			13	3	6	8	5	10	9	10			5		4	5	7	9	16	17
26—50	87	3	6			1	1	8	5	10	75	5	8			.	.	3	9	11
51—75			1	.											.	..	..	..	..	..
>75				.			.						..		.	.	..	..	..	..
3 0 Km.																				
6—25			14	7	..	4	9	16	16	10			7	3	2	3	10	17	17	14
26—50	81	2	2	.	.		1	9	5	5	59	3	3	.	.	.	3	2	3	8
51—75			.	..	.	.	.						..	..	..	.	..	..	2	2
>75			..	.	..	.	..	..	.	..			.	..	..	..	..	..	..	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr. or less.

*0·5 km. is above surface , all other heights are above m.s.1.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SANDOWAY.

Speed limits km./hr	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			MAY.										JUNE.							
Surface.																				
6—25	93	*96*		.	2	.	1	1		.	98	*94*				1	3	2		..
26—50						.														..
0 5 Km*																				
6—25			23			5	6	2	22	34			1		1	4	21	15	7	1
26—50	88	*2*					6				82	*6*				2	32	9		
51—75							1										1	.		
>75																		.		
1 0 Km																				
6—25			1			1	3	4	43	43						1	11	14	14	13
26—50	74	*1*				4	3	1	1	5	70	*0*				1	29	11	1	
51—75				.			1								.	.	3	4	.	
>75				.		.												.		
2 0 Km.																				
6—25			10	2	2		6	13	11	21			3			3	10	7	23	5
26—50	68	*5*	5			2	6	2	5	11	40	*7*	.	.		3	17	13	5	3
51—75			.				2										3			
>75																		.		
3 0 Km.																				
6—25			12	16		4	8	14	4	18			12	12			12	16	16	8
26—50	49	*0*	8			4	4	4			25	*0*					4	12	4	
51—75					..														.	
>75														.			.	4		
			JULY.										AUGUST.							
Surface.																				
6—25	124	*73*		1	2	3	6	15	1	1	124	*85*		2	1	2	3	6	2	
26—50																	.		.	
0 5 Km.*																				
6—25				1	1	10	18	10	5	5			6		1	2	15	18	6	15
26—50	88	*1*				2	20	20	1		97	*8*					8	11	4	1
51—75							1	3									3			..
>75			.		.				.								.			..
1 0 Km.																				
6—25			3		2	9	19	7	7				1		1	1	8	18	28	12
26—50	58	*2*				3	14	22	7	2	76	*0*			1		5	12	5	5
51—75								7							.	.		1	..	..
>75																.			.	..
2 0 Km																				
6—25			3	3	3	14	17	3	10	7					.	2	13	23	32	6
26—50	29	*0*	.				10	17	7	3	47	*2*					4	2	9	2
51—75					.	.									2		2		.	..
>75				.					.					.	.	.			.	..
3 0 Km																				
6—25			5	5		10	19	14	5	5			3	.	7	3	23	23	13	7
26—50	21	*0*	5	.	.	10	5	10	10		30	*17*		.	.	3	.	.	.	..
51—75			.	..	.	.		..						.	.	.	..	..	..	..
>75			..	..	.	..	..	..	..				..	.	..	..	..	..	.	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr or less.

*0·5 km. is above surface, all other heights are above m.s.1.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SANDOWAY.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	SEPTEMBER.										OCTOBER.									
Surface																				
6—25	120	*93*		1	1	3	1	2		1	124	*97*		2	1	.			1	..
26—50																		.		..
0 5 Km.*																				
6—25			14		5	10	27	12	7	5			31	11	9	12	11	2	.	6
26—50	108	*6*			2	2	7	3		1	122	*13*			2	1	2		1	..
51—75																				.
>75																			..	..
1 0 Km.																				
6—25			6	.	4	6	15	16	11	11			6	13	16	15	8	3	4	14
26—50	85	*4*		1	4	2	7	11	1	1	118	*8*			2	8	2	1	.	..
51—75					1												2			..
>75																				.
2 0 Km																				
6—25					4	19	18	19	10	4			3	8	26	22	8	5	4	6
26—50	52	*6*		2	2	4	2	4	6		109	*2*			7	4	3		..	..
51—75					2											3	1	.		.
>75																			.	..
3·0 Km																				
6—25				6	6	31	6	6	11				2	7	28	17	8	2	6	5
26—50	36	*11*				14	3	3			99	*9*		1	6	4	1	1		..
51—75						3										1	1		.	.
>75																		.	.	..
	NOVEMBER										DECEMBER.									
Surface.																				
6—25	120	*97*		1	2						124	*98*			2			.	..	..
26—50																			.	..
0 5 Km.*																				
6—25			25	18	18	8	6	2		3			25	15	24	10	2		..	5
26—50	119	*13*		1	3	1	2		1		124	*15*		2	2				.	..
51—75																			..	..
>75																			.	..
1 0 Km.																				
6—25			6	11	18	14	8	5	5	8			6	10	16	15	11	7	6	15
26—50	118	*12*		2	5	1	3				124	*12*			2					..
51—75							1			.									..	..
>75					.														.	..
2 0 Km.																				
6—25			3	4	12	17	15	13	12	7			4	5	6	10	15	15	15	14
26—50	113	*4*				5	4	1		1	123	*4*			1	1	4	5	1	2
51—75							1											.	.	..
>75			.															.	.	..
3 0 Km																				
6—25			6	4	7	10	14	13	10	16			7	3	1	4	4	16	21	14
26—50	102	*7*	3		1	1	6		1	3	112	*3*	1	3		.	1	6	11	6
51—75													1			.	.	.	..	..
>75																			.	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr. or less.

* 0·5 km. is above surface, all other heights are above m.s.l.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SILCHAR.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			JANUARY.										FEBRUARY.							
Surface																				
6—25	93	91		1	5	2		.		..	82	89	.	2	7	1		.		
26—50						..														.
0 5 Km.*																				
6—25	76	0	1	7	74	9	4	4	1		75	8			53	23	8	5		
26—50			..				..								1			1		
51—75			.				.	.							.				.	.
>75																				
1 0 Km.																				
6—25	76	20		20	18	5	8	18	7	4	73	18		7	11	11	14	23	14	3
26—50				.		..	.		.				.			1		3		
51—75																				
>75						..														
2 0 Km.																				
6—25	73	0	4	3	4	3	12	19	11	5	64	5	5	2	2	2	8	17	30	6
26—50							.	8	22	8					2		.	2	20	2
51—75																	.			
>75																				
3 0 Km.																				
6—25	40	0	..			.		3	5		33	0					.	6	15	6
26—50								10	35	3							3	6	33	6
51—75					.			.	30	13							.		18	3
>75									3								.		3	.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			MARCH.										APRIL.							
Surface.																				
6—25	98	78	1	4	15	1					89	78		6	16	1				
26—50																				
0 5 Km.*																				
6—25	93	10	1	5	31	15	16	8	10	2	80	13	1		23	23	13	9	8	4
26 50				.	.		.		1						3			3	3	
51--75				.	..	.	..	..	.	.						.		1		
>75				.				.		..										
1 0 Km.																				
6—25	90	9		7	7	1	7	38	18	1	72	4	1	4	1	3	10	36	15	3
26—50				.				11	2							..	3	17	1	
51—75					.										.	.			1	
>75				.																
2 0 Km.																				
6—25	81	1	5	1		.	2	10	21	9	50	0	2	2	2	.		2	22	8
26—50					.		..	10	32	1			.	.	.		2	10	38	4
51—7o								4	4				.	.					8	.
>75													.						..	..
3·0 Km.																				
6—25	53	0	2		2	2		2	15	9	19	0		5			5		16	11
26—50							2	19	17					..		.	.	5	26	11
51—75									23					..		.	..		16	5
>75					.				6	2				.	..	..		..	.	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr or less.

0 5 km is above surface, all other heights are above m.s.l.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SILCHAR.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	MAY.										JUNE.									
										Surface.										
6—25	90	*84*		9	4	1	.		..	1	90	*86*	..	2	6	3	..	..	1	2
26—50				..		..		.	.				.	.				..	..	..
										0 5 Km.*										
6—25			3	5	33	10	13	10	10	4			6	6	13	10	13	10	11	6
26—50	79	*6*			3		.	1	..	1	63	*22*	.		.		3	.	..	.
51—75																.	.		..	..
>75								.		.			.	.		.	.	.	..	..
										1 0 Km.										
6—25				4	4	1	17	37	12	1			.		5	2	14	29	5	5
26—50	76	*4*				.	9	9	3		56	*5*			2		16	14		
51—75							..	1					.			.		2	.	.
>75																			.	
										2 0 Km.										
6—25				2			2	21	16	2				3	3	10	10	35		
26—50	57	*2*						28	25	2	31	*3*					6	19	6	
51—75							2													.
>75																.		3		.
										3 0 Km.										
6—25								29		.				.			16	62	8	.
26—50	21	*0*			.				33		13	*0*	.					8	8	
51—75									33	5										
>75									.									.	.	
	JULY.										AUGUST.									
										Surface.										
6—25	93	*95*	.	2	2		..	.	..	2	93	*86*	.	3	8	1	.	1	.	1
26—50				.			..		.	.								.	..	
										0 5 Km.*										
6—25			5	9	15	11	12	15	8	6			3	5	18	8	15	10	10	3
26—50	65	*17*						2			60	*17*			3			3		.
51—75															3					
>75														.		.	.			
										1 0 Km.										
6—25					9	4	19	23	4					8	10	2	17	6	8	4
26—50	52	*4*					10	15	..		52	*13*	.		12		4	12		
51—75						.	.	..		.					4		2			
>75								.	.						.					
										2·0 Km.										
6—25			6	.	3	21	19	19							11	26	16		5	
26—50	32	*0*		..	3		13	9			19	*0*			11		5	16		.
51—75				.	.	3	.	3	.						5		5	.		.
>75				.		.		.	.										.	..
										3·0 Km.										
6—25				..		25	13	19	6					20	20	.	20	20		.
26—50	16	*6*	.	.	13		6	6			5	*0*				20				
51—75			.	.	..	6	.	..	..	.						.		.	..	.
>75			.	.	.	.	..	.	.								.	..	.	.

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

SILCHAR.

Speed limits km/hr.	n	C	N	NE	E	SE	S	SW	W	NW	N	C	N	NE	E	SE	S	SW	W	NW
					SEPTEMBER										OCTOBER.					
Surface.																				
6—25	76	*93*		1	4					1	93	*98*		1	1		..			..
26—50																				..
0 5 Km.*																				
6—25				5	30	7	14	5	9	5				3	68	12	3	6		1
26—50	56	*18*			5						66	*5*			1					
51—75																				
>75																				.
1 0 Km.																				
6—25				10	23	2		19	8	2			3	15	27	3	8	7	7	3
26—50	48	*10*			13		6	6			60	*23*			2					
51—75																				
>75																				..
2 0 Km																				
6—25			3	14	17	14	3	21	14	3			4	2	8	6	10	24	20	10
26—50	29	*3*			3			3			50	*2*			2		2	4	2	2
51—75															2					
>75																				..
3 0 Km																				
6—25					36	14	14		14	7							3	30	47	3
26—50	14	*7*				7					30	*0*					7	3	7	
51—75																				
>75																.				

Speed limits km/hr.	n	C	N	NE	E	SE	S	SW	W	NW	N	C	N	NE	E	SE	S	SW	W	NW
					NOVEMBER.										DECEMBER.					
Surface.																				
6—25	88	*87*		2	10						93	*91*	1	2	4	1			.	
26—50																				.
0 5 Km.*																				
6—25				1	80	1	8							1	80	10	1	1		.
26—50	74	*5*			3			1			79	*2*			4					..
51—75																				
>75																				
1 0 Km.																				
6—25			1	10	38	16	4	10	1	3				14	33	21	9	3	4	1
26—50	73	*4*			3						78	*10*			5				.	
51—75																				
>75																				
2 0 Km.																				
6—25			1	5	3	9	15	33	15	5				8	12	21	13	19	12	4
26—50	66	*11*			1			1			75	*3*			3	1		1	1	1
51—75																			.	.
>75																			.	.
3 0 Km.																				
6—25			2		7	2	2	7	12	2			3	3	8	5	5	5	16	3
26—50	41	*0*						12	34	5	38	*5*			3			..	26	10
51—75								.	7	5							.	3	3	3
>75			.											.		..	..	..	.	..

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C represents the percentage number of cases when speed was 5 km/hr. or less.

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NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

VICTORIA POINT.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	JANUARY.										FEBRUARY.									
Surface.																				
6—25	93	*24*		72	4					.	84	*19*	..	76	5	.	..	.		..
26—50																.		.	.	..
0 5 Km.*																				
6—25			4	4	41	10							10	7	24	17		1	..	6
26—50	93	*3*		4	32						84	*23*		1	10	1				
51—75					1										1		.			..
>75							.										.			.
1 0 Km.																				
6—25			2	6	12	5							2	7	25	8	2	1	5	2
26—50	93	*1*		3	60	1					84	*6*		2	33	5			.	
51—75				1	8								.							.
>75																.		.		
2 0 Km.																				
6—25			5	11	22	7							2	10	28	15	1		5	.
26—50	85	*2*		2	40	4					82	*4*		4	28	2		.		.
51—75					5	1									1					.
>75					1														.	..
3 0 Km.																				
6—25				11	32	14		2	3	2			2	7	39	10	5	2	5	3
26—50	66	*2*	2	6	24	3					59	*3*			15	5		.	2	2
51—75					2													.		..
>75									.	.							.	.	..	..
	MARCH.										APRIL.									
Surface.																				
6—25	93	*33*		57	10			.	.		90	*42*	.	46	4	2	.	2	1	2
26—50																	..	..	..	..
0 5 Km.*																				
6—25			3	3	25	20	2	2	6	17			8	2	7	11	2	10	17	20
26—50	93	*18*			3						90	*19*			1	1	.	..	1	..
51—75																	.	1	..	..
>75																	.	..	.	..
1 0 Km.																				
6—25			4	7	29	11	4	1	8	10			7	4	14	9	1	14	16	22
26—50	90	*7*		1	16	2					85	*5*			9	6	.	1	1	..
51—75							.										.		.	..
>75							.									..	.	.	..	..
2 0 Km.																				
6—25			1	6	28	19	2	1		2			5	7	34	16	3	3	8	1
26—50	86	*2*		5	29	2	1				73	*1*		1	7	5	.	..	3	1
51—75			.		1	.								.	1	.	..	1	..	..
>75			.		.		.						.	.		.	.	.	..	..
3 0 Km.																				
6—25			..	4	21	27	3	1	1	1			3	20	25	17	.	5	3	..
26—50	67	*1*		9	27	4					60	*2*			12	7	2	3	..	2
51—75			.	..		.	.			.			.	.	.	..		..	..	..
>75			.	.		.	..		.	.			.	.	.	..	.	.	..	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr. or less.

* 0·5 km. is above surface, all other heights are above m.s.l.

NORMAL PERCENTAGE FREQUENCIES OF SURFACE AND UPPER WINDS.

VICTORIA POINT.

Speed limits km./hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
			MAY.										JUNE.							
Surface																				
6—25	93	*40*	.	27	2	10	2	15	1	3	90	*56*		8	1	10	3	14	6	1
26—50					.								.				..	1	.	..
0 5 Km.*																				
6—25			2	2	7	2	4	12	28	6			1				4	27	25	4
26—50	90	*4*			-		1	23	4	2	84	*4*		.				21	13	1
51—75			.			.		1						.	.				.	..
>75				.	.		.								.		.			
1 0 Km.																				
6—25			1	1	8	9	5	3	16	8					1		3	7	14	4
26—50	75	*3*			1			17	16	3	71	*1*						'24	35	3
51—75								7	1									1	6	
>75																..		.		.
2 0 Km.																				
6—25			2	4	15	17	2	6	2	9			2		2	5	2	11	8	5
26—50	58	*4*			8	4		8	15	2	44	*5*	.					7	36	
51—75								2	2										7	
>75																				
3 0 Km.																				
6—25			6	6	33	18	3	6	3	3				5	14	5	5	18		14
26—50	33	*3*			3	3		3	3		22	*5*				5		5	18	
51—75								6											5	.
>75																	.		5	.
			JULY.										AUGUST.							
Surface.																				
6—25	93	*47*	.	1	1	2	2	31	14		93	*43*		10	5	4	2	20	1	2
26—50								1											.	
0 5 Km.*																				
6—25				.			1	19	10				4	2	.	1	6	15	21	6
26—50	91	*0*			.			46	13	.	85	*4*				.	.	26	9	1
51—75								8	3						.			5		..
>75																			..	..
1 0 Km.																				
6—25							2	10	14				4	.	4	?	4	12	21	5
26—50	68	*0*	.					19	19	2	76	*3*					.	12	20	.
51—75							.	27	6					.		.		8	3	1
>75									2					.			.		.	..
2 0 Km.																				
6—25						3	16	11	8				6	8	10	6	10	15	8	2
26—50	37	*0*			.	.		8	30		48	*4*	.	2	.	.	.	4	13	..
51—75					.			3	19	3			.		.			.	10	..
>75					..	.			.				.	.	..	..	.	.	..	..
3 0 Km.																				
6—25					3	19	19		7	7			12	.	36	24	4	8	..	4
26—50	15	*0*			.		13		13		25	*0*		.	4	.	4	.	4	..
51—75						..		.	.	..			.	.	..	..	.	..	..	..
>75			..	.	.	.	.		7	..			.	..		..	..	..	..	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km./hr. or less.

*0·5 km. is above surface, and all other heights are above m.s.l.

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Speed limits km /hr.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
				SEPTEMBER.										OCTOBER.						
										Surface.										
6—25	89	*46*		4		4		28	9	7	97	*46*	..	39	4	5	2	2	.	1
26—50									1										.	..
										0 5 Km.*										
6—25					1			14	27				8	5	13	5	10	18	16	4
26—50	84	5						21	24		91	*5*		2	5			5	1	..
51—75								5	2					.						..
>75								.		.				.						..
										1 0 Km.										
6—25			2	2	2	3	2		17	2			6	12	12	5	8	6	8	8
26—50	64	*0*						14	41		78	*9*		.	10	1		4	10	1
51—75								5	13										..	.
>75																.			.	..
										2 0 Km.										
6—25					6	6	3	3	9	9			2	14	26	12	9	3	9	5
26—50	32	*0*			3				37	3	66	*2*		2	6	3		3	6	..
51—75								3	16									..		..
>75																.		.		.
										3 0 Km.										
6—25					29	7			29	14			2	8	30	24	14	2	2	2
26—50	14	*0*						7	14		50	*2*			12	2	.	.	.	..
51—75																.		..		.
>75																			..	.
				NOVEMBER										DECEMBER.						
										Surface										
6—25			1	63	6	2							2	74	4	1	1	.	..	..
26—50	120	*28*									124	*15*			1	.		.	..	..
										0 5 Km*										
6—25			7	7	21	7	2	7	4	3			6	6	19	5	1	2	..	2
26—50	116	*8*		11	21			2			122	*3*	.	13	35	1	..		..	..
51—75				1									.	2	5	.	.		.	..
>75										.			.				.		..	..
										1 0 Km.										
6—25			5	11	19	8	2	3	5	5			2	11	14	10		2	.	..
26—50	110	*3*		6	19	3		1		1	121	*2*		7	43	3	.	1	..	..
51—75					7			1						1	6			.	..	..
>75					1												.	.	..	..
										2 0 Km.										
6—25			3	16	22	14	3	1	3	4			4	9	28	10	5	3	4	5
26—50	90	*4*		3	20	2				1	108	*5*	1	6	13	4	.	1	2	..
51—75					1										2		.	.	..	..
>75			.												.		.	..	..	..
										3 0 Km.										
6—25			4	15	24	22		6	4				7	12	16	14	6	5	4	6
26—50	67	*3*		6	10	3					85	*7*	2	5	9	4	1	1	1	..
51—75					1									..	..	..		..	..	..
>75				.										.	.	..		..	..	..

n represents the total number of observations and

C represents the percentage number of cases when speed was 5 km /hr or less.

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INDIA METEOROLOGICAL DEPARTMENT

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BY

A. ANANTHAPADMANABHA RAO, B.A.

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A NOTE ON THE STATISTICAL STUDY OF RAINFALL IN MYSORE STATE*

BY

A. ANANTHAPADMANABHA RAO, B.A.

(*Received on 3rd May 1935.*)

Abstract.—This paper deals with a statistical analysis of the mean annual rainfall of the Mysore State, its districts and each of the individual taluk headquarter stations in the three malnad districts of Kadur, Hassan and Shimoga, the period considered being 40 years (1893-1932). The average annual rainfall of the State is 38·17 inches. The rainfall series are subjected to polynomial fitting up to 5th degree in time and it is observed that secular variations are generally absent except in Kadur district where there is a significant upward trend. Correlation coefficients between the rainfall of each of the districts after the removal of secular changes from the data are examined. They show that the whole State can be divided into two homogeneous groups, the malnad and non-malnad tracts.

1. Introduction.

Annual rainfall with its seasonal distribution is one of the important meteorological factors determining crop yield. A statistical analysis of the annual rainfall in Mysore state and its districts has been attempted in the present paper with a view to study the variability, the secular trends if any and rainfall correlations in the different districts. On the basis of these correlations the state is grouped into homogeneous regions with respect to rainfall.

The annual rainfall data are available from the year 1893 in the "Reports on rainfall registration in Mysore" (1), published annually by the Mysore Meteorological Department. Mr. Cook's Memoir on the "Meteorology in Mysore for 1893-94" (2) contains some useful information regarding the rainfall of the State previous to 1893, *i.e.*, from 1875.

The state (see *Fig. 1*) consists of 8 districts, Bangalore, Kolar, Tumkur, Mysore, Hassan, Shimoga, Kadur and Chitaldrug. Each district is divided into taluks and there has been at least one rain-gauge in each taluk since 1893. The number of

* This study was taken up by the author (now Meteorological Observer, Government Coffee Experimental Station, Balehonnur, Mysore State), while he was under training in Agricultural Meteorology at Poona.

rain-gauge stations has been increasing continuously in the State. For purposes of statistical analysis, the rainfall of only A. Class stations, *i.e.*, of taluk headquarters, which have been in existence since 1893, has been considered. This ensures homogeneity of the data*, so that any trend shown by the data would not be due to the effect of averaging from a variable number of stations.

Table A gives the number of A. Class raingauge stations in each district with the area of each district in square miles.

TABLE A.

District.	No. of "A" Class stations.	Area of district in square miles.
Bangalore	10	3,068
Kolar	11	3,164
Tumkur	10	4,061
Mysore	13	5,488
Hassan	8	2,665
Shimoga	9	4,030
Kadur	7	2,788
Chitaldrug	9	4,159
Mysore State .	77	29,423

In all taluks except Bangalore, Mysore, Hassan and Shimoga there has been one raingauge since 1893. In Bangalore taluk there have been four, in Hassan taluk 3, in Mysore taluk 2, and in Shimoga taluk 2 raingauges since 1893. In each of these four cases the average of the gauges in use has been considered.

2. Distribution of rainfall.

Table 1 gives the annual rainfall during the 40 years under consideration in this paper and *Table 2* gives the mean annual rainfall (M), the standard deviation (s) and the coefficient of variability (V) for the state as a whole and for each of the 8 districts.

* The annual rainfall figures from the year 1917 are different from those found in Table V of the rainfall registration reports for Shimoga district and Mysore State The following footnote appears in the report for 1917, " the figures given for Nagar are those recorded by the rain-gauge at Kallurkatte which is the headquarters of the Nagar taluk The figures given in previous reports are those recorded at Nagar itself " As the rainfall at Kallurkatte is on the average less than that at Nagar, an error would be introduced into the calculations made in this paper by the use of the averages for the state and for Shimoga district published by the Meteorological Department. On this account fresh averages from 1917 onwards have been calculated for Shimoga district and for the State, utilising the rainfall figures from Nagar town to avoid non-homogeneity of the data.

Mysore State receives rainfall from both the south-west and the north-east monsoons. Rain associated with thunderstorms usually falls in April and May. The south-west monsoon sets in about the latter part of first week or the beginning of the second week of June and continues till about the end of September. The western portion of the state comprising mostly the malnad districts of Shimoga, Kadur and Hassan receives much rain until the end of September when the retreat of the south-west monsoon begins. The north-east monsoon sets in after the retreat of the south-west monsoon ; the three malnad districts do not, however, receive as much rain during this season as the rest of the state.

The mean annual rainfall of the state is 38·17 inches. The annual rainfall was highest (51·12″) in 1903 and lowest (27·51″) in 1899. Kadur district has the highest mean annual rainfall of 72 inches and Shimoga district has 71 inches. Chitaldrug district receives the least mean annual rainfall of 23 inches. Some portions of this district receive on an average less than 16 inches of rain. The three districts of Hassan, Shimoga and Kadur, through the western taluks of which the western ghats run, receive more than 40 inches. Some places near the ghats receive very heavy rainfalls (see *Fig. 1*), the note-worthy places being Byrapur estate (299″) and Kottgehar toll-gate (204″) in Mudigere taluk, Aralgode (211″) in Sagar taluk and Maranahally toll-gate (208″) in Manjarabad taluk. It is interesting to note that Agumbi and Hulikal in Shimoga district lying on the very edge of the ghats receive on the average 327″ and 353″ of rainfall per year respectively. The mean annual rainfalls for the district and taluk headquarters are entered in *Fig. 1.*

3. Variability of rainfall.

The standard deviation (s) of rainfall for the state as a whole and for the eight districts gives an idea of the distribution of rain about its mean value (M). For purposes of comparison of this variation, from place to place, the coefficient of variability (V) obtained from $\frac{s \cdot 100}{M}$ is also given in *Table 2.* The variability of rainfall in the state and in the different districts varies from 16% in Hassan district to 25% in Tumkur district. It can be seen that V varies from 20% to 25% in the case of non-malnad districts and from 16% to 19% in the three malnad districts of Hassan, Kadur and Shimoga. Thus the districts of heavy rainfall have on an average less variability than districts of light rainfall.

4. Secular changes.

The annual rainfall for the state and for each of the districts has been examined for secular changes. Then the rainfall of each of the individual A class stations in the three districts of Shimoga, Kadur and Hassan has been examined for similar secular variations. The curves plotted in *Fig. 2* appear to indicate secular trends in Kadur, Hassan and Bangalore. To examine whether these trends in the state and the district annual rainfall are real, the forty years' rainfall data have been subjected to a statistical analysis by fitting polynomials of the fifth degree in time by the method developed by Fisher ([4]). Fisher's notation is used in this paper.

The values of the six distribution constants are given in *Table 3.*

In *Table 4* are given the values of x'_2, x'_3 . . . . x'_6, which represent the secular changes, the significance of which can be tested by the standard error. The value of x' to be significant should be at least twice as much as the standard residue.

It may be seen from *Table 4* that Bangalore district in general shows a downward trend while the two districts of Kadur and Hassan show a general upward trend as

judged by the values x'_2. The trend in the case of Kadur alone is significant. The values of x'_4 and x'_5 are fairly high for some districts but not significant when compared with their standard errors. The state considered as a whole does not show any trend in the annual rainfall.

A detailed investigation of rainfall in each of the seven "A" class stations in Kadur district, as well as in Shimoga and Hassan districts was undertaken in order to locate the exact regions in the malnad portion of the state where trends are present. These three districts with the exception of their eastern portions are very mountainous and are fully covered with forests.

Tables 5, 6 and *7* give the annual rainfall during the 40 years under consideration in this paper for each of the "A" Class stations in Kadur, Shimoga and Hassan districts respectively. *Table 8* gives the mean annual rainfall (M), standard deviation (s), the coefficient of variability (V), the value of x'_2 indicating the straight line effect and the standard residue. Out of the seven sub-stations in Kadur district, Sringeri and Narasimharajapura indicate in general an upward trend, of which the latter alone is significant. In Shimoga district, Sagar and Nagar indicate in general upward trends which are not significant, whereas the downward trend for Shimoga taluk may be considered to be significant. In Hassan district, the upward trends indicated by Manjarabad, Arkalgud and Channarayapatna are not significant. A similar analysis for each of the taluk headquarter stations in the other five districts is nearing completion and an attempt will be made in another paper to see to what extent the variations in the area of reserve forests and the growth of trees in the reserve forests influence these trends in rainfall.

5. Polynomial Values.

For constructing the graphs and examining the deviations, the polynomial values have been calculated for the state and for each of the eight districts. These polynomial values are given in *Table 9*, and are plotted in *Fig. 2* (dotted lines).

6. Inter-district correlations.

In order to group the districts into homogenous zones with respect to rainfall, their intercorrelation coefficients are worked out. First of all, the correlation coefficients between the rainfall of each of the districts, without considering secular changes, are determined. These are given in *Table 10*. In view of the fact that certain districts showed some indications of progressive changes, the coefficients after the removal of such changes are determined. These fresh correlation coefficients given in *Table 11* are used for grouping the districts into homogenous zones. According to Fisher (4) the numerically highest random correlation coefficient for 35 degrees of freedom and for 5% and 1% level of significance are 0·32 and 0·42 respectively. Out of 28, 19 coefficients are above the 1% level of significance.

Applying the tables extending Walker's Criteria given by Savur and Gopal Rao (5) the 5% chance highest value of a correlation coefficient in a group of 28 coefficients is 0·47. Even when such a rigorous test as this is applied, all the 19 coefficients out of the 28 are greater than 0·47. Out of these 19, only one coefficient, *i.e.*, that between Tumkur and Shimoga, is negative and the rest are positive.

The conclusions that can be drawn from *Table 11*, are :—

1. The districts, Bangalore, Kolar, Tumkur, Mysore and Chitaldrug are highly inter-correlated.

2. The districts of Shimoga and Kadur are also highly correlated with each other.

3. Hassan district occupies an intermediate position having high correlations with all districts.

4 Shimoga district is negatively correlated with Bangalore, Kolar, Tumkur and Chitaldrug of which that with Tumkur alone is significant. On the other hand, it is positively correlated with Hassan, Kadur and Mysore of which that with Mysore alone is not significant.

Thus the whole state may be broadly divided into two groups, the malnad districts and the non-malnad districts. The former comprises Kadur and Shimoga and the latter Bangalore, Kolar, Tumkur, Mysore and Chitaldrug. Hassan district occupies an intermediate position between these two groups. This grouping may be helpful for purposes of forecasting rain-fall in the state.

In conclusion, I wish to express my thanks to the Director General of Observatories, India Meteorological Department, for having permitted me to work in the Agricultural Meteorology section of the Meteorological Office, Poona. The Mysore data were chosen for study at the suggestion of Mr. S. L. Malurkar and I am thankful to Dr. Ramdas and Dr Kalamkar for their valuable help in carrying out the above investigation. I am thankful also to the Director of Agriculture, Mysore State, Bangalore, for the facilities given to me in his office to continue this investigation after my training.

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[4] R. A. Fisher, Statistical methods for research workers, IV Edn.

[5] Tables extending Walker's Criteria and for finding the chance of success of a forecast, by S R. Savur and S Gopal Rao, India Met Dept. Sci. Notes, Vol. 5, No. 49

TABLE (1).—*Mean Annual (January—December) rainfall in inches for Mysore State and for each of its districts.*

Year.	Bangalore.	Kolar.	Tumkur.	Mysore.	Hassan.	Shimoga	Kadur.	Chitaldrug.	State.
1893 ..	41 01	29 85	33 04	36·04	40·44	56·04	58·36	28·53	39·03
1894 .	33 71	26 09	23 71	24·37	31·87	55·59	51·06	19·09	31·63
1895 ..	36 07	32 83	31·29	27 88	32·62	63·75	55·22	22·81	36·36
1896 ..	29 31	24·33	19 96	25·54	45 24	106·57	90·25	17·45	40·67
1897 ..	37 56	30 14	32 88	33 06	42 04	70·03	72·08	25·66	40·63
1898 ..	35 54	32 45	32 35	34 52	42 06	73 09	70·18	29·11	41·48
1899 ..	24 37	22 75	23 72	21 14	27 31	46 77	46·19	19 11	27 51
1900 .	28·73	28 35	22·17	27·03	44·89	84·60	63·09	16·79	36 60
1901 .	34 35	27 75	28·27	32 94	39·51	70·14	61·23	21·38	37·29
1902 .	29 86	33 47	27 64	27 17	41 92	74·24	66·22	26·54	38·49
1903 .	51 66	49 78	36·74	46 30	54 65	68·71	83·18	31·04	51·12
1904 ..	26 16	22 73	21 19	21 49	36 88	69·31	70·31	17·80	33 28
1905 .	27 94	23 64	20·69	22 58	32 43	48 31	53·40	17·41	29·29
1906 .	40·16	33 78	34·26	28·73	42·87	60 50	64·08	27·56	39 91
1907 ..	27 02	26·06	21·58	26 53	42 77	82 34	94 41	19 60	39 46
1908 .	25 49	16 09	15 76	24 24	27 98	67·31	63·74	14·03	29 94
1909 .	39 93	30 21	30 99	36 48	44 98	69·76	78·53	23·81	42·44
1910 .	42 38	38 58	35·92	33·83	45 99	72 09	76·33	30·63	45 12
1911 ..	28·12	23 51	19 84	30 68	43 39	70 91	69·33	17·53	35 91
1912 .	41 19	33 50	30 68	29 02	50 42	85·25	89 95	28 48	45·73
1913 ..	26 70	23 57	22·26	25 01	33 36	69·27	64·40	18·66	33 54
1914 ..	24 05	20 29	19 90	22·31	37·74	89·18	83·32	17·28	36 31
1915 ..	32·59	32·60	32·94	34 23	41·34	59 98	67·13	26·72	39 65
1916 .	39·85	39·41	40 18	43·50	48 03	76·71	76·97	29·67	47·79
1917 .	36·59	34 85	38 51	31 28	40·33	68·21	71·73	34·84	42·73
1918 ..	23 84	19·40	20·15	22·52	35·74	51·24	51·39	20·55	29 03
1919 ..	36 62	35 74	32·19	29·18	42·71	65·09	69·89	26 95	40·48
1920 ..	23 88	19·77	16·45	25·15	32·78	57·15	61·74	16·82	29·95
1921 .	30 10	31·05	25·00	30 43	38·17	63·56	71·23	23·96	37·37
1922 ..	31·06	26 95	26 60	28 78	36 73	60·05	69·86	20 11	35·71
1923 ..	21·00	15 19	13 72	21 60	46 10	101·41	103 18	16·70	38·24
1924 ..	28 26	25 52	23·96	30 98	49·94	84·61	99·42	20·73	42·16
1925 ..	26 32	27 65	25 74	24·71	39·71	80·52	76·84	22·41	37·99
1926 .	27·72	28 76	24·09	25·10	40·08	67 72	71·76	19·41	35·91
1927 ..	25·86	26 12	21 31	19 49	35 40	62·90	74·64	18·27	33·07
1928 .	29 73	27·43	28 89	28 48	42 09	64·84	63·40	24·24	36·86
1929 ..	30·16	30 96	27·33	29·87	47·28	76·63	77·76	26 42	40·79
1930 ..	33·40	37·62	29·58	33·88	43·24	61·33	66·13	25·76	39·87
1931 ..	23 53	22·49	21·28	25·98	48·00	80·33	83·58	21·35	37·71
1932 ..	37·27	35 68	35·64	36·02	57·35	91·36	93·34	35·91	49·77

TABLE (2).—*Mean Standard Deviation and the Coefficient of Variability of mean annual rainfall of the State and its districts.*

Districts.	Bangalore.	Kolar.	Tumkur	Mysore.	Hassan.	Shimoga.	Kadur.	Chitaldrug.	State.
Mean (M) in inches.	31·73	28·67	26·71	28·95	41·16	70·69	71·87	23·02	38·17
Standard Deviation (s).	6·67	6·78	6·60	5·89	6·62	13·18	13·29	5·39	5·44
Coefficient of Variability in % (V).	21·02	23·65	24·71	20·34	16·02	18 64	18·49	23·40	14·25

TABLE (3).—*Distribution constants for the State and for each of the districts for mean annual rainfall.*

Constants.	a′.	b′.	c′.	d′.	e′.	f′.
Bangalore	31·7350	—1·1274	+0 0714	+0 1811	+0·0471	—0·0382
Kolar	28 6725	—0 1742	+0·1786	+0 3743	+0·1667	+0 0764
Tumkur	26·7075	—0 3225	+0 1879	+0·1437	+0·3909	+0·1719
Mysore .. .	28·9475	—0 2253	+0 0549	+0 2122	+0 3748	+0 1261
Hassan	41·1550	+1·0527	+0 3197	+0 6357	+0 2497	+0·1497
Shimoga	70·6850	+1·0701	+0 3245	+0 6541	—0·0255	+0·5395
Kadur	71 8700	+2·8048	—0·3112	+0 5088	+0 1060	+0 1350
Chitaldrug	23·0225	+0·2585	+0·2641	+0·2105	+0·4279	+0 2165
State	38·1705	+0·3486	+0·0935	+0·3316	+0·4041	+0·0871

TABLE (4).—*Values of* x'_2 x'_3 x'_6 *and the Standard Residue for the State and for each of the districts.*

——	x'_2.	x'_3.	x'_4.	x'_5.	x'_6.	Standard Residue.
Bangalore	—12·67	+1 09	+3 52	+11·49	—1·18	6·49
Kolar	—1·95	+2 72	+7 28	+4 07	+2 34	7·17
Tumkur	—3 62	+2 87	+2 81	+9·53	+5·25	6·75
Mysore	—2 53	+0 84	+4 13	+9·14	+3 85	6·01
Hassan	+11·83	—4 87	+12 36	+6·09	+4 59	6·27
Shimoga	+12 02	+4 96	+12 71	—0 65	+16·48	13·48
Kadur	+31 50	—4 74	+9 84	+2 58	+4·18	13·01
Chitaldrug	+2·90	+4·03	+4·09	+10·43	+6 62	5·25
Mysore State	+3·92	+1 42	+6·45	+9·85	+2·66	5·40

TABLE (5).—*Annual Rainfall (January—December) at each of the Taluk Headquarters in Kadur District.*

Year.	Chickmagalur.	Kadur.	Tarikere.	Koppa.	Mudgere.	Narasimharajapura.	Sringeri.
1893	34 80	27 21	33·39	110·94	93·76	50·08	..
1894	29 74	13 96	25·65	115·38	74·11	47·48	..
1895	37 92	20 91	28·90	107·09	86·83	49·66	..
1896	48 93	24 99	46 77	178·72	165·63	75·57	..
1897	39 46	18 56	33·78	150 06	130 97	59·62	..
1898	37 67	34 98	44 86	141 05	86 62	75·85	148·19
1899	28 22	21·15	32 41	82·43	64 98	47·95	115·53
1900	29 89	14·57	42·64	No reading	139 98	88·36	213·82
1901	36 45	19·44	34 70	130 32	81·35	64·97	164·29
1902	38 37	36 21	35 47	113·37	102 25	71·66	124·91
1903	41·90	29·80	47 15	127 89	103 20	69 80	162·53
1904	34 34	17 43	30 33	113 79	89 73	67·17	139·37
1905	24·61	15·89	33·25	89 12	69 80	47·52	94·23
1906	39 10	26 15	38·91	93 44	77 13	54·90	118·94
1907	41 77	23 82	39 71	159 06	114 86	87 87	193·77
1908	21 74	11 44	23 65	114 41	77 83	62 39	134·73
1909	44 59	25 88	36 49	117·82	110 71	81 68	132·51
1910	48 40	27 57	38 05	110 82	99 73	82 67	127·05
1911	40 53	19 16	30 90	106 99	82 74	76 43	128·57
1912	48 00	32 43	39 60	132 55	127 86	80 43	168·75
1913	29 75	16 17	25 89	103·12	86 70	66 93	122·24
1914	34 46	17 50	40 82	130 64	90 58	94 78	174·46
1915	35 98	27 57	44 51	93 86	83 36	71 37	113·29
1916	35 67	27 85	33 88	123 90	91 40	82 74	143·32
1917	40 12	28 29	40 51	103 92	85·35	76 00	127·89
1918	27 67	19 36	25 30	68 58	66·81	53 20	98·83
1919	41 26	29 62	40 11	91 52	83 23	68 01	135 51
1920	24·86	15 76	23 96	94 21	81·45	59 93	131·94
1921	27 26	15 28	41·08	112 50	95·31	74 04	133·12
1922	30 34	28 35	31 78	114 52	70·03	59 00	155·05
1923	37 88	22 71	38 85	177 67	116 93	115 13	213·14
1924	42 68	24 06	38 05	151 56	130·31	105 18	204 07
1925	31 35	18 00	33 36	117 23	87·80	80 39	169·72
1926	35 30	18 11	34 02	106 54	92 87	63 47	151·62
1927	27 24	19 87	36 44	113 53	95·45	80 20	149 76
1928	26 21	28 28	36 78	88 53	81·60	59 21	133 21
1929	40 26	33 80	37 14	113 09	92·05	73 57	154 46
1930	29 78	22·64	32 25	103 68	72·18	62·66	139·74
1931	36·61	19·57	37 84	135·60	110·26	79·23	165·98
1932	45·16	45 61	54·55	140·37	111·58	95·11	161·04
1933	..	..	..	..	..	..	173·53

Table (6).—*Annual Rainfall (January—December) at each of the taluk headquarters in Shimoga District.*

Year.		Shimoga. (Hospital)	Channagiri.	Honnali	Shikaripur.	Sorab.	Sagar.	Nagar.	Thirthally.	Kumsi.
1893	..	38 81	30 98	21 56	31 25	56 60	71 65	144 90	96 81	37·50
1894	..	27 54	19 91	14 83	27 29	58 60	60 31	166 91	99·87	26 48
1895	..	37 89	26 48	19 87	31 05	61 45	81 80	174 00	106 68	35 85
1896	..	49 34	30 35	31·37	46 91	92 87	122 84	370 77	159 46	55·78
1897		33 84	28 29	23 47	29 67	66 82	84 43	200 61	129 37	39 24
1898	..	43 53	40 61	35 07	42 89	69 02	87 18	166 54	123 18	52 29
1899	..	28 12	24 56	16 80	30 81	44 58	46 41	130 09	76 51	27·67
1900	..	40 95	25 65	15 58	38 32	68 32	104 68	265 22	167 42	40·05
1901	..	35 94	24 75	30 30	40 38	55 01	77 49	196 83	130 52	41·38
1902	.	43 09	34 45	31 61	54 27	75 15	100 28	159 09	118 70	52·15
1903	.	34 19	28 89	32 30	42 00	53 52	80 15	172 52	126 71	50·54
1904	..	36 20	24 25	20 72	34 47	62 31	78 32	210 10	116 47	42·62
1905	..	27 46	23 59	17 85	21 90	35 22	48 07	153 55	84 81	25 77
1906	..	39 14	37 80	23 04	29 06	47 59	71 19	162 01	94 40	39·40
1907	..	35 28	30 41	18 80	41 68	69 64	100 24	251 41	151 31	45 38
1908	..	23 01	19 95	13 99	31 38	60 62	86 65	201 61	133 59	35·19
1909	..	37 82	26 70	15 93	37 81	72 16	81 06	184 66	127 21	46 11
1910	..	32 06	41 30	24 68	34 74	71 27	92 66	189 46	116 60	46 74
1911	.	30 22	27 48	25 99	36 69	62 43	74 60	223 66	119 64	56 78
1912	.	39 89	29 68	23 96	13 49	75 65	96 63	261 23	150 85	46 32
1913	.	32 26	29 31	28 05	37 30	56 89	77 56	215 14	108 34	41 56
1914	.	32 53	29 19	19 44	40 15	82 09	102 61	310 11	119 89	40 63
1915	..	31 57	33 50	23 71	28 34	60 97	65 14	156 94	99 30	39·26
1916		28 46	37 18	34 61	43 92	72 90	82 87	216 52	124 29	47 18
1917	..	33 34	36 50	31 67	34 79	51 80	76 52	197 35	116 93	39·95
1918	..	21 60	19 79	19 36	26 86	45 48	57 08	154 17	84 52	32 69
1919	..	30 01	41 65	24 87	27 94	48 94	63 00	200 02	107 73	40·49
1920	..	24·31	26 75	20 12	23·74	46 56	63 70	171 29	98 90	35·55
1921	..	30 65	25 57	15 40	32 20	52 09	79 10	191 95	108 91	35 74
1922	..	26 37	25 37	21 53	20 49	50 47	71 37	197 27	95 54	31 95
1923	..	40 43	24·31	21 00	47 27	80 64	135 18	320 03	176 16	50·59
1924	..	36·88	22·44	18 88	36 35	61 84	114 69	262 76	157 40	50·15
1925	..	31·76	27·14	28 06	38·14	65 23	99 59	251 23	135 21	44·95
1926	..	26 10	22·90	23 10	29 98	51·07	74·08	224 60	118 28	38·00
1927		30 78	30 24	18 06	26·28	50·22	70 62	199 44	109 63	35·86
1928	..	32 07	31 99	26 16	41 32	58 78	72 14	181 14	99 14	38·23
1929	..	41·23	39 43	28·30	43 84	62 70	94 18	223 99	120 19	43·63
1930	..	24·08	29·16	25·51	30 38	54·73	72·86	172 65	102 25	36·59
1931	..	28·80	30·04	28·54	39·74	74·14	101·00	244 88	137·08	34·83
1932	..	44·23	42·57	25·79	56·32	82·46	92·18	270·25	155·30	55·20

TABLE (7).—*Annual Rainfall (January—December) at each of the taluk headquarters in Hassan District.*

Year.	Hassan (Observatory).	Manjarabad.	Arkalgud.	Belur.	Channarayapatna.	Arsekere	Hole-Narasipur.	Alur.
1893	.	80 25	34·57	42·60	32·78	28·37	34·93	31·77
1894	..	61·42	34 08	32 38	24·81	15 87	18·02	14·45
1895	.	75·15	25·16	31·55	23·85	31·17	26·72	No reading.
1896	.	137 93	37·87	49 15	17·12	20 83	26 65	33·13
1897	.	101 83	37 87	43 22	28 26	26·45	29·87	35·30
1898	39 83	91 63	40 51	38 57	34 40	27·74	32·91	38·71
1899	27·30	59 18	22 84	33 88	17·20	21·75	16·68	19·66
1900	42·71	121 61	33 14	52·14	26·83	28·62	24·51	29·52
1901	33 46	96 51	38 41	36 00	28·37	22·01	29 22	32·06
1902	42 49	82 92	41 99	58 29	21 49	31 22	27·91	46·12
1903	50 89	104 72	55 62	50 34	43 70	34 70	41 98	53 68
1904	30 83	88 13	34·10	34 40	16·84	27 79	26 54	36 41
1905	24·09	65·46	34 60	31·29	18 64	24 95	24 01	36·37
1906	41·83	82 03	34 60	35 69	32·25	35·16	31 60	49 81
1907	34 44	107 97	37 99	43 49	21 07	16 00	27 41	53 81
1908	20 08	73 73	27 62	24 24	14 72	11 35	22 40	29 71
1909	42 22	93 15	34 40	44 16	33 99	32 89	28·73	50 33
1910	37 86	97 77	35 85	54 69	34 67	26·79	32·30	48 00
1911	33 17	97 58	41 00	40 90	32 68	26 17	31 46	44·14
1912	40 17	102 32	46 91	57 38	34 49	32 06	30 27	59·12
1913	25 76	85 48	23 36	31 05	19 21	27 19	19 71	35 09
1914	31 53	93 35	36 28	40 25	22 31	15 11	21 79	41·30
1915	35 54	80 73	36 46	38 60	37 29	27·71	30 18	44·20
1916	43·49	94 89	46 08	44 70	39 17	35 46	37 11	43 30
1917	40 50	73 12	35 44	41 05	28 37	28·18	32 39	43 57
1918	27 56	66 36	31 18	32 39	32 79	33 28	24 85	37 53
1919	35 86	85 15	41 76	33 08	41 37	35 00	30 16	39 31
1920	28·12	76·45	28 56	32 70	21 76	18 01	19·13	37·44
1921	33 25	93 29	40 07	35 99	22 49	22 39	25 69	35 50
1922	29 82	72 53	36 87	38 43	30 23	27 71	28 05	30·19
1923	31·93	120 56	58 92	42 27	22 31	20 30	26 82	45·65
1924	41 39	114 95	60 26	53 75	27 68	24 58	28 01	48·87
1925	32 88	94 64	48 13	35 49	21 23	16 57	25 16	43·59
1926	32 11	92 51	46 30	35 64	25 21	26 05	29 02	33·80
1927	26·80	90·38	28 67	32 66	21·63	18 36	25 53	39·19
1928	31·95	100 49	34·99	33 54	30 52	32·79	32 67	39·79
1929	37·12	125·35	33 34	41 87	31 05	34 90	24 08	50·56
1930	38 20	108·43	35 23	35 52	33·19	29·84	27·77	37·77
1931	43·50	132·62	34·72	45·70	33·03	19·69	27·39	47·37
1932	43·15	151·35	44·90	53 31	42·20	41·63	34·64	48·06
1933	46 86	..	..	..	..		..	..

TABLE (8).—*Statistical constants for Annual rainfall for each of the taluk stations in Shimoga, Kadur and Hassan Districts.*

Taluk Stations.	No. of years considered.	Mean Annual rainfall in inches. (M)	Standard deviation (s)	Co-efficient of variability (V)	x'_2.	Standard Residue.
SHIMOGA DISTRICT—(9).						
(1) Shimoga (Hospital)	40	33 54	6·51	19 41	—12·07	6·29
(2) Channagiri . .	40	29 53	6 20	21 00	+ 6·03	6 21
(3) Honnali .	40	23 51	5 70	24 25	+ 3·53	5 74
(4) Shikaripur . .	40	35 75	8 19	22 91	+ 2 82	8·28
(5) Sorab . ..	40	61 74	12 23	20 00	— 3·07	12·41
(6) Sagar . .	40	82 81	18 81	22 71	+11·94	19·00
(7) Nagar .	40	208 67	51 24	24 55	+71·2	50·50
(8) Thirthally .	40	120 89	23 89	19 76	+ 42·6	23·20
(9) Kumsi . .	40	40 75	7 33	17 99	+ 1 75	7·44
KADUR DISTRICT—(7)						
(1) Chickmagalur	40	35 66	6 96	11 10	— 4 94	7·08
(2) Kadur .	40	23 50	7 15	30 42	+ 7 14	7·16
(3) Tarikere . .	40	36 10	6 59	18 25	+ 4 59	6·70
(4) Koppa ..	40	117 15	23 93	20 43	—11 31	24·16
(5) Mudgere .	40	95 13	20 11	21 14	—15 52	20·2
(6) Narasimharajapura ..	40	71 56	15 67	21·89	+37·50	14·67
(7) Sringeri . .	36	147 75	29 22	19·78	+30 2	29·20
HASSAN DISTRICT—(8)						
(1) Hassan (Observatory) ..	36	35 54	6 99	19·67	+2 13	7·09
(2) Manjarabad . ..	40	94 52	20 87	22 08	+37 50	20·21
(3) Arkalgud .. .	40	37 77	8 42	22 18	+12 69	8·28
(4) Belur .. .	40	40 31	6 48	16 08	— 1 68	6 57
(5) Channarayapatna ..	40	28 03	7·52	26 82	+10·21	7·45
(6) Arsikere	40	26·81	5 61	20·93	+ 6·43	5·59
(7) Hole-Narasipur ..	40	27·86	5·12	18·37	+ 1·1	5·19
(8) Alur	40	36·75	14·71	40·03	+ 8·51	14 77

TABLE (9).—*Polynomial values for the mean Annual Rainfall (January—December) for the State and for each of the Districts.*

Year.	Bangalore.	Kolar.	Tumkur.	Mysore.	Hassan.	Shimoga.	Kadur.	Chitaldrug.	State.
1893	38·8	28·1	29·2	30·4	35·7	58·3	57·8	23·6	37·9
1894	36·5	28·6	29·0	30·1	37·1	64·3	60·2	23·7	37·5
1895	34·7	29·0	28·6	29·8	38·2	68·5	62·2	23·6	37·2
1896	33·5	29·3	28·2	29·5	38·9	71·1	63·8	23·3	36·9
1897	32·7	29·4	27·7	29·1	39·5	72·5	65·0	22·9	36·7
1898	32·2	29·5	27·2	28·9	39·8	73·1	66·1	22·6	36·6
1899	32·0	29·5	26·8	28·7	40·1	73·0	66·9	22·2	36·7
1900	32·0	29·5	26·5	28·6	40·3	72·5	67·6	21·9	36·8
1901	32·1	29·5	26·2	28·5	40·4	71·8	68·2	21·6	36·9
1902	32·4	29·5	26·1	28·5	40·5	70·9	68·8	21·5	37·1
1903	32·7	29·5	26·0	28·6	40·6	70·1	69·3	21·4	37·4
1904	33·0	29·4	26·0	28·8	40·7	69·3	69·7	21·5	37·7
1905	33·4	29·4	26·1	29·0	40·8	68·7	70·2	21·7	38·1
1906	33·7	29·4	26·3	29·2	40·9	68·2	70·6	21·9	38·4
1907	33·9	29·3	26·6	29·4	41·0	68·0	71·0	22·2	38·7
1908	34·1	29·3	26·8	29·7	41·1	67·9	71·4	22·6	39·0
1909	34·1	29·3	27·1	29·9	41·2	68·1	71·9	23·0	39·3
1910	34·1	29·2	27·4	30·1	41·3	68·4	72·3	23·4	39·5
1911	34·0	29·1	27·6	30·3	41·3	68·9	72·6	23·7	39·6
1912	33·7	29·0	27·8	30·4	41·4	69·4	73·0	24·0	39·7
1913	33·4	28·8	27·9	30·4	41·4	70·0	73·3	24·3	39·7
1914	33·0	28·7	28·0	30·4	41·3	70·6	73·6	24·4	39·6
1915	32·4	28·5	27·9	30·2	41·2	71·1	73·9	24·5	39·4
1916	31·9	28·2	27·8	30·0	41·1	71·5	74·1	24·4	39·1
1917	31·2	28·0	27·5	29·6	40·9	71·8	74·2	24·2	38·7
1918	30·5	27·7	27·1	29·2	40·7	72·0	74·3	23·9	38·3
1919	29·8	27·4	26·6	28·7	40·4	71·9	74·3	23·4	37·9
1920	29·1	27·1	26·1	28·2	40·2	71·7	74·4	22·9	37·4
1921	28·5	26·8	25·4	27·6	39·9	71·4	74·4	22·3	36·9
1922	27·9	26·6	24·8	27·0	39·7	70·9	74·4	21·7	36·4
1923	27·4	26·4	24·2	26·5	39·6	70·3	74·5	21·1	36·0
1924	27·1	26·3	23·7	26·0	39·7	69·8	74·6	20·5	35·8
1925	26·9	26·3	23·3	25·7	39·9	69·4	74·8	20·2	35·7
1926	27·0	26·5	23·1	25·6	40·4	69·2	75·1	20·1	35·9
1927	27·3	26·9	23·3	25·8	41·2	69·5	75·7	20·5	36·4
1928	27·8	27·6	23·8	26·4	42·5	70·4	76·6	21·3	37·2
1929	28·7	28·5	25·0	27·5	44·3	72·2	77·9	22·7	38·6
1930	30·0	29·9	26·8	29·1	46·8	75·1	79·5	25·0	40·5
1931	31·7	31·7	29·4	31·5	50·1	79·5	81·8	28·3	43·2
1932	33·8	34·0	33·1	34·8	54·3	85·8	84·7	32·8	46·6

TABLE (10).—*Correlation Co-efficients between each of the Districts in the Mean Annual rainfall before the removal of secular changes.*

District.	Bangalore.	Kolar.	Tumkur.	Mysore.	Hassan.	Shimoga.	Kadur.
Kolar.. ..	+0·87	..	..	..	..	..	..
Tumkur ..	+0·87	+0·89					
Mysore ..	+0·82	+0·79	+0·79	..	..	..	..
Hassan ..	+0·48	+0·55	+0·46	+0·62	..	..	..
Shimoga ..	—0·08	+0·01	—0·56	+0·04	+0·61	..	..
Kadur ..	+0·04	+0·09	—0·004	+0·18	+0·72	+0·84	..
Chitaldrug ..	+0·77	+0·83	+0·92	+0·73	+0·58	+0·01	+0·15

TABLE (11).— *Correlation Co-efficients between each of the districts in the Mean Annual rainfall after the removal of secular changes.*

District.	Bangalore.	Kolar.	Tumkur.	Mysore.	Hassan.	Shimoga.	Kadur.
Kolar.. ..	+0·91	..	..	..	..	..	..
Tumkur ..	+0·89	+0·90	..	..	..	..	..
Mysore ..	+0·84	+0·80	+0·77	..	..	..	..
Hassan ..	+0·63	+0·58	+0·50	+0·66	..	..	..
Shimoga ..	—0·05	—0·02	—0·64	+0·01	+0·61	..	..
Kadur ..	+0·17	+0·09	+0·01	+0·21	+0·70	+0·87	..
Chitaldrug ..	+0·85	+0·86	+0·93	+0·71	+0·58	—0·08	+0·11

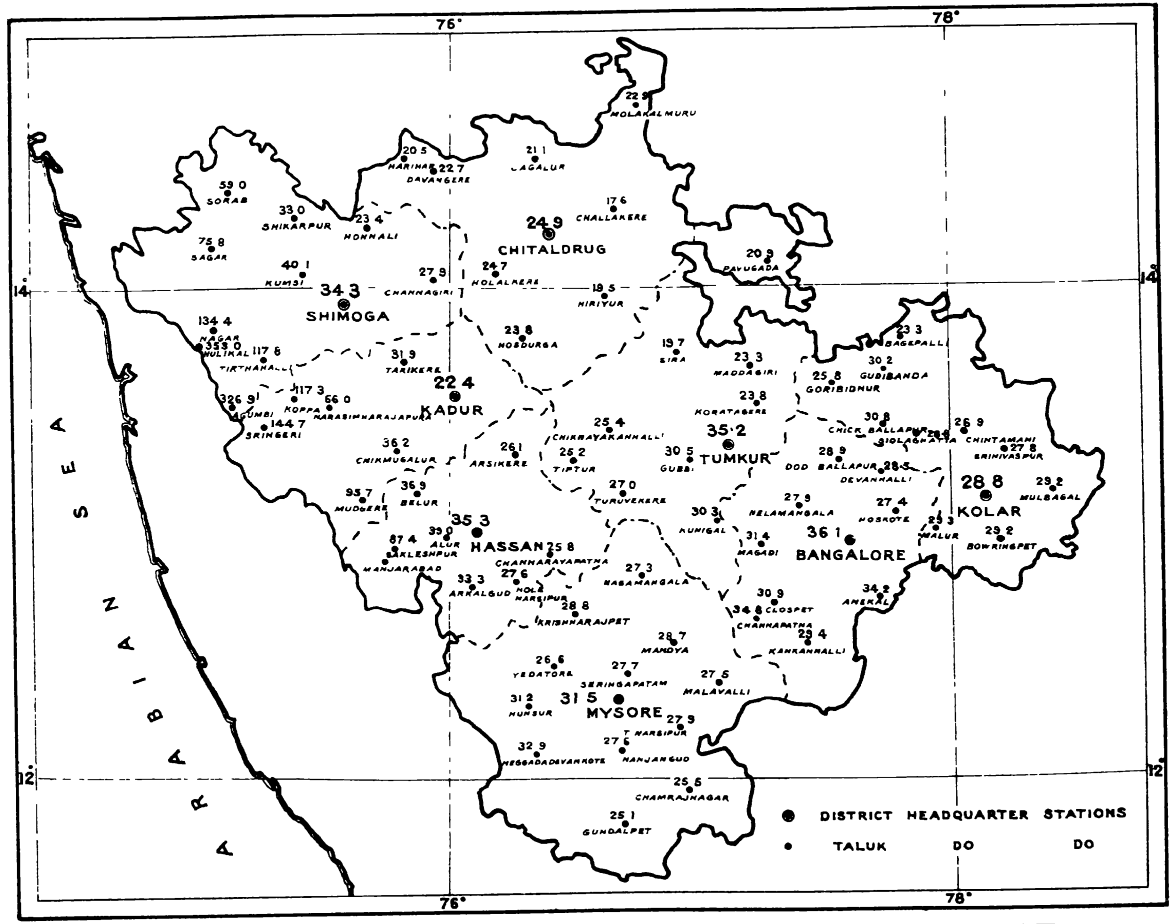

FIG. 1. MAP OF MYSORE STATE SHOWING AVERAGE ANNUAL RAINFALL

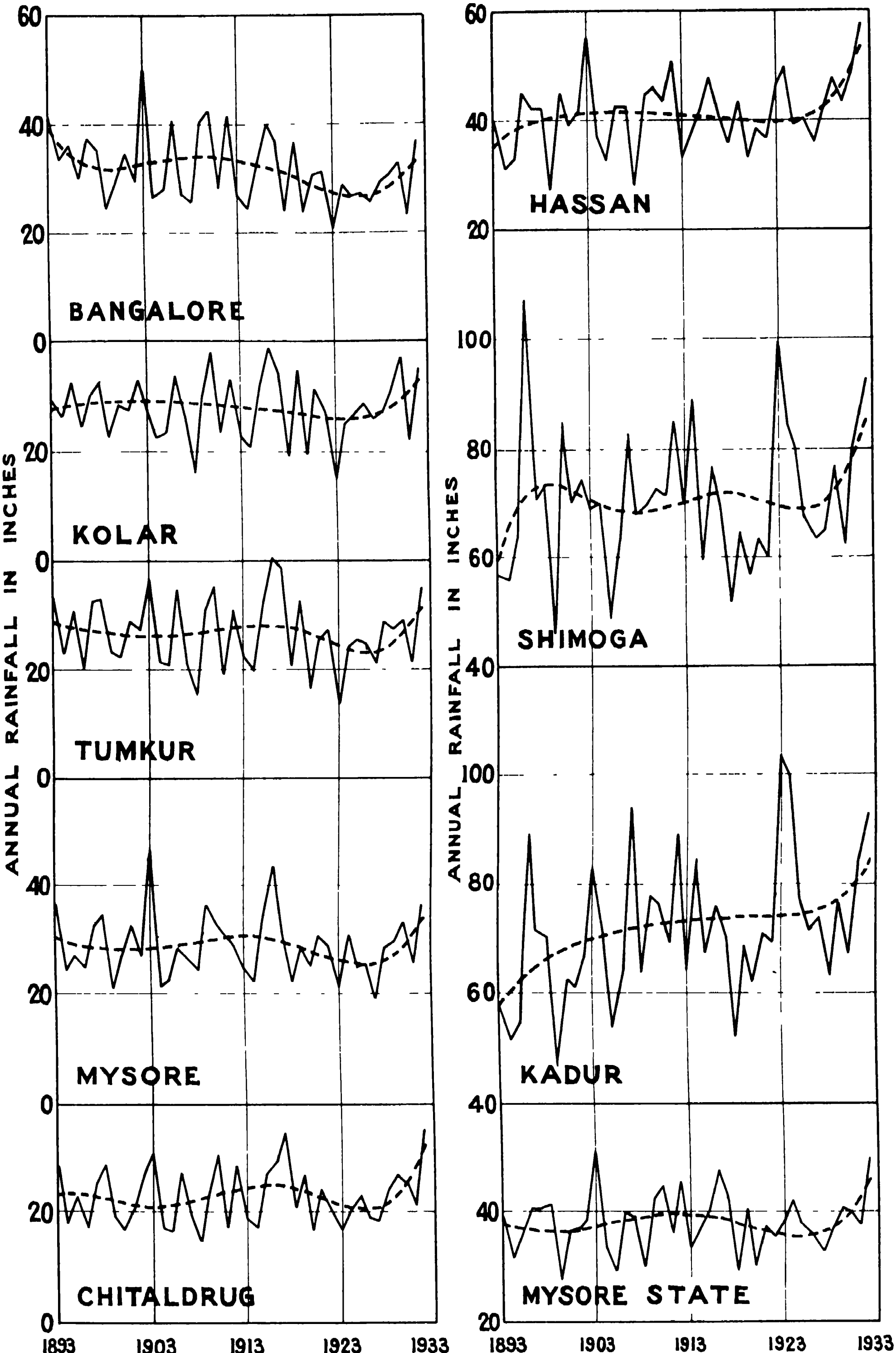

FIG. 2. ANNUAL RAINFALL FOR THE EIGHT DISTRICTS AND THE MYSORE STATE

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BY

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A STUDY OF CORRELATION COEFFICIENTS OF MEAN MAXIMUM TEMPERATURES BETWEEN SUCCESSIVE MONTHS AT A FEW SELECTED STATIONS IN INDIA *

BY

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(*Received on 30th October 1935.*)

Abstract.—The analysis indicates that stations with high inter-monthly correlations, group themselves in an interesting manner and that the centres of high correlation show a definite movement with the march of the seasons. The centre of high correlation is strong and lies over South India during winter, it is feeble and is roughly over Sind and adjoining areas in North-west India during the Southwest monsoon. Over the rest of the country the correlations increase slightly during clear weather and decrease during the wet months. The movement of the centre of high correlation appears to be associated with the movement of the sub-tropical belt of high pressure which exists in the upper levels between 2 Kms. and 4 Kms.

1. Introduction.—In an earlier investigation (1) the author had worked out correlation coefficients of the mean monthly maximum temperatures between successive months at Poona and had observed that the autumn and winter months at Poona are significantly correlated with each other.

This investigation is extended in the present paper to a few selected stations in India to discover the relation, if any, between the periods of high inter-monthly correlation coefficients of mean monthly maximum temperatures and the seasonal changes in weather. Further, such an analysis is likely to indicate the period for which there is a possibility of forecasting temperatures over a shorter period of time, say, a week or 5 days, from the knowledge of the temperatures prevailing in weeks preceding.

2. The maximum temperature data and their inter-correlations.—The 19 stations in India selected for this study are shown in *Table I*. The data of the maximum temperatures for the selected stations extend over a variable period of 39 to 57 years. The number of years available for each of the stations is given against them in *Table I*, where the average maximum temperatures for the different months and their standard deviations and coefficient of variability are also given. Appropriate corrections were applied to the mean maximum temperature in the case of stations where changes in the site or method of exposure of the thermometer had taken place.

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* The present investigation was made in the Agricultural Meteorology Branch (India Meteorological Department) financed by the Imperial Council of Agricultural Research.

TABLE I.

Maximum Temperatures. °F.

Station.	Years.		Jany	Feby	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Lahore	54		67·2	70·5	82·8	95·0	103·8	106·2	99·5	96·4	96·8	93·3	81·9	71·5
		S.D.	3·3	4·1	4·6	3·7	4·3	2·6	3·5	3·5	3·1	2·4	2·4	2·7
		C.V.	4·9	5·8	5·5	3·9	4·1	2·4	3·5	3·6	3·2	2·6	2·9	3·8
Jacobabad	53		72·9	78·2	91·0	102·5	111·6	113·4	108·3	104·0	103·3	98·9	87·3	75·9
		S.D.	3·3	4·4	4·3	3·3	3·6	2·4	2·6	2·8	2·1	1·9	2·5	2·6
		C.V.	4·5	5·6	4·7	3·2	3·2	2·1	2·4	2·7	2·0	1·9	2·8	3·4
Bikaner	49		71·8	76·7	89·1	99·9	107·2	107·3	101·5	97·8	98·3	96·1	85·8	75·1
		S.D.	3·2	4·3	3·9	3·9	3·3	2·2	2·8	2·6	2·9	2·2	2·1	2·4
		C.V.	4·5	5·6	4·4	3·0	3·1	2·0	2·8	2·7	3·0	2·3	2·5	3·2
Agra	57		72·9	77·7	89·9	100·9	106·6	104·9	95·1	92·0	93·6	93·2	84·3	75·2
		S.D.	2·9	3·5	3·7	3·5	3·1	3·1	3·9	3·7	3·7	3·1	2·3	2·1
		C.V.	3·9	4·5	4·1	3·4	2·9	2·9	4·1	4·1	3·9	3·3	2·7	2·7
Patna	55		72·8	77·7	89·9	99·0	100·2	96·4	90·5	89·1	89·7	88·5	81·7	74·4
		S.D.	2·1	2·6	3·1	3·0	2·9	3·7	1·8	1·4	1·6	2·1	1·7	1·5
		C.V.	2·9	3·4	3·5	3·1	2·9	3·9	2·1	1·5	1·8	2·3	2·1	2·1
Dhubri	48		73·6	77·7	86·1	87·6	85·9	85·6	86·0	86·3	85·5	84·5	79·6	74·3
		S.D.	1·6	2·1	2·9	3·1	1·9	1·6	1·4	1·2	1·5	1·5	1·4	1·2
		C.V.	2·1	2·7	3·4	3·5	2·3	1·8	1·6	1·4	1·7	1·8	1·8	1·6
Karachi	55		75·6	77·3	82·0	86·0	89·3	90·8	88·7	85·3	85·7	87·3	84·7	78·8
		S.D.	2·3	2·7	2·2	2·1	1·6	1·4	1·7	1·6	1·4	1·7	1·7	1·9
		C.V.	3·1	3·5	2·7	2·4	1·8	1·6	1·9	1·8	1·6	2·0	2·1	2·4
Ahmadabad	39		84·5	87·7	96·6	104·4	107·3	101·8	93·1	89·9	93·5	97·0	93·4	86·2
		S.D.	2·3	2·7	2·9	1·8	2·1	3·2	3·6	2·7	3·0	3·0	2·5	1·9
		C.V.	2·7	3·1	3·0	1·7	1·9	3·1	3·9	3·0	3·2	3·1	2·7	2·2
Jubbulpore	55		77·6	81·6	92·1	100·8	105·3	98·3	86·5	84·5	87·1	87·1	81·8	77·1
		S.D.	2·3	2·7	3·0	2·6	2·7	4·2	2·6	1·9	1·8	2·5	2·4	1·8
		C.V.	3·0	3·4	3·3	2·6	2·5	4·3	2·9	2·2	2·1	2·9	3·0	2·4
Calcutta	55		77·7	82·5	91·5	95·7	94·9	91·7	88·6	88·0	88·5	87·6	82·3	77·2
		S.D.	1·9	2·3	2·9	2·1	1·9	2·5	1·0	1·1	1·1	1·4	1·5	1·2
		C.V.	2·4	2·8	3·2	2·3	2·0	2·7	1·1	1·2	1·3	1·6	1·8	1·6
Akola	57		86·2	90·6	99·1	105·8	108·2	99·3	89·4	87·4	89·6	92·5	88·0	84·5
		S.D.	2·3	2·5	2·5	2·2	1·9	3·7	2·0	2·1	2·7	3·2	2·7	2·5
		C.V.	2·7	2·7	2·5	2·1	1·8	3·7	2·2	2·4	3·0	3·5	3·1	3·0
Sambalpore	55		81·7	86·5	95·9	103·2	106·4	97·9	87·5	86·7	88·8	88·8	83·7	79·8
		S.D.	2·1	2·6	3·3	3·1	2·7	4·7	2·1	1·5	1·5	1·6	1·7	1·7
		C.V.	2·6	3·0	3·5	3·0	2·6	4·8	2·3	1·7	1·7	1·8	2·1	2·2
Bombay	55		83·1	83·1	86·2	89·0	91·1	88·4	84·9	84·4	85·1	88·1	87·7	85·0
		S.D.	1·7	1·4	1·4	1·3	1·4	1·5	0·9	0·9	1·2	1·5	1·7	1·4
		C.V.	2·1	1·7	1·6	1·4	1·6	1·7	1·1	1·1	1·4	1·7	2·0	1·6
Poona	52		86·4	90·6	97·3	101·2	99·8	90·0	82·6	81·8	84·6	89·2	86·7	84·8
		S.D.	1·7	1·8	1·9	2·1	1·8	2·7	1·7	1·5	1·9	2·8	1·8	1·9
		C.V.	2·0	2·0	1·9	2·1	1·8	3·0	2·1	1·8	2·2	3·2	2·1	2·3
Hyderabad	41		84·3	89·7	96·9	101·4	103·6	95·3	87·6	86·3	86·6	88·1	84·2	82·4
		S.D.	2·2	2·1	2·5	2·4	2·7	3·0	1·9	2·0	1·9	2·5	2·6	2·0
		C.V.	2·6	2·3	2·6	2·4	2·6	3·1	2·2	2·3	2·2	2·8	3·1	2·5
Mangalore	44		89·1	88·6	90·1	91·7	90·9	85·4	83·7	83·5	84·1	86·3	88·6	89·4
		S.D.	1·1	1·2	0·9	1·1	1·3	1·0	1·1	1·0	0·9	1·3	1·5	1·1
		C.V.	1·3	1·3	1·0	1·2	1·5	1·2	1·3	1·2	1·1	1·5	1·7	1·3
Bangalore	53		81·4	86·4	91·4	93·7	92·0	85·2	82·3	82·2	82·5	82·3	80·1	79·2
		S.D.	2·0	1·6	1·5	1·6	2·2	1·7	1·8	1·5	1·7	1·5	1·9	1·9
		C.V.	2·4	1·8	1·6	1·7	2·4	2·0	2·2	1·8	2·1	1·8	2·4	2·4
Madras	55		84·3	86·7	89·8	93·2	98·6	99·3	96·1	94·3	93·1	89·3	85·1	83·3
		S.D.	1·2	1·0	0·9	1·0	2·2	2·4	2·1	2·1	1·7	1·7	1·5	1·1
		C.V.	1·4	1·1	1·0	1·1	2·2	2·3	2·2	2·2	1·9	1·9	1·8	1·4
Trivandrum	43		84·0	85·6	87·6	88·0	86·6	83·0	82·0	82·4	83·0	83·0	82·8	83·3
		S.D.	0·9	0·9	1·0	1·2	1·3	1·1	0·9	1·0	1·0	0·8	0·9	0·8
		C.V.	1·1	1·1	1·1	1·4	1·5	1·4	1·1	1·2	1·2	1·0	1·1	0·9

The table brings out in an interesting manner the march of the maximum temperatures at each station from month to month. While the difference between the highest and the lowest maximum temperature for Agra, Bikaner, Lahore and Jacobabad varies from 34° to 40°F, that for the three coastal stations Bombay, Mangalore and Trivandrum varies from 6° to 8°F, for the other coastal stations Madras, Karachi and Calcutta it varies from 14° to 18° F and for other inland stations the range is from 19° to 28°F.

The lowest maximum temperatures generally occur in December and January while the highest are recorded in the months of April, May or June. It is interesting to note that in the case of Poona, Mangalore and Trivandrum, however, the lowest mean maximum temperature of the year occurs in July or August. Most of the stations show a secondary maximum in September or October. The coefficient of variability varies from ·9 to 5·6 per cent. The coefficient of variability for most of the inland stations is higher for the months of June and October which are characterised by the setting in of the monsoon and its withdrawal respectively. Jacobabad, Bikaner and Agra, however, show the highest coefficient of variability in the month of February.

A preliminary analysis of average maximum temperatures for different months over a series of years at various stations did not indicate any apparent secular trends In the case of Poona the maximum temperatures for the months of January and February had actually been subjected to a statistical analysis by fitting a polynomial of the fifth degree to investigate the trend if any. The analysis indicated the absence of any secular trend.

Correlation coefficients of maximum temperatures between successive months for each of the nineteen stations have been worked out in the usual manner and are given in *Table II*. The values of the correlation coefficients for the 5 and 1 per cent levels of significance [2] for 38 degrees of freedom are ·31 and ·40, and for 50 degrees of freedom ·27 and ·35 respectively. Using Walker's criterion as extended by Savur and Gopal Rao [3], the 5% chance highest values of a correlation coefficient occurring in a group of 12 correlations for 39 and 57 years are ·55 and ·37 respectively.

It is interesting to note that significant correlations for the stations are noticeable during definite periods of the year. The actual values of the correlation coefficients of maximum temperatures between successive months are plotted in *Figures 1 to 12* where lines of equal correlation coefficients are also drawn These figures show that the stations with high inter-monthly correlations group themselves in an interesting manner and that the centres of high correlation show a definite movement with the march of the seasons.

TABLE II.

Maximum Temperature Correlations between successive months.

Station.	Jan.-Feb.	Feb.-March.	March-April.	April-May.	May-June.	June-July.	July-Aug.	Aug.-Sept.	Sept.-Oct.	Oct.-Nov.	Nov.-Dec.	Dec.-Jan. (next).
Lahore ..	·44	·26	·16	·12	—·09	28	·36	22	·55	41	·34	·39
Jacobabad	·30	·18	·40	·45	24	43	·50	70	63	·59	·40	·32
Bikaner ..	·37	·44	·45	·32	·16	·47	·46	·32	·68	·44	·09	·44
Agra ..	·40	·43	·49	·49	·04	·49	·12	·59	·67	·24	·15	·41
Patna ..	·25	·59	40	·34	·19	16	35	50	37	·56	53	26
Dhubri .	·22	·53	·15	37	11	15	19	11	12	·52	·57	·03
Karachi .	·36	·27	·53	25	·30	48	·59	·62	26	31	28	·36
Ahmadabad	·38	·30	46	17	33	55	43	33	62	·67	36	·38
Jubbulpore	·42	50	38	42	15	36	·07	·12	71	64	·35	·11
Calcutta ..	·39	·62	·28	44	30	20	39	59	58	61	61	·25
Akola .	·48	·53	·41	35	17	32	16	19	70	71	53	·43
Sambalpore	·46	·57	·39	45	·07	·15	·15	31	59	58	32	·25
Bombay ..	·54	42	·68	47	21	34	36	45	46	64	69	46
Poona .	·45	·40	40	35	40	29	14	10	51	91	85	·51
Hyderabad	·45	·58	31	35	·37	·19	36	·28	·61	74	65	65
Mangalore .	·32	·40	61	48	36	06	29	33	·32	51	57	·36
Bangalore	·70	·63	25	35	47	27	53	50	·27	62	71	·74
Madras ..	67	47	·13	18	22	37	50	46	— 24	40	43	58
Trivandrum	·62	67	44	48	34	37	45	46	34	65	39	58

3. The seasonal movement of the main centre of high correlations.—An examination of *Figures 1 to 12* shows that during the period May to August (*Figures 4 to 7*) the inter-monthly correlations are generally low In August-September (*Figure 8*) the correlations, which have a tendency to improve in July-August over Sind, show a further increase over that area With the retreat of the monsoon from North India the correlations generally increase over north-west India and the area of highest correlations moves south-eastwards and lies over the central parts of the country in September-October (*Figure 9*). In October-November (*Figure 10*) the 'high' moves further southwards and lies over the north Deccan As the winter sets in the southward movement continues and during the period November-February (*Figures 11, 12 and 1*) the high correlation area remains over south India, the correlations over North India are poor during this period when the winter depressions affect this area. When the hot weather sets in, the 'high' weakens and begins its northward movement (*Figures 2, 3 and 4*). With the beginning of May and later as long as the monsoon conditions persist, the correlations become poor as mentioned earlier

To sum up, the centre of high correlations is strong and lies over South India during winter, it is feeble and is roughly over Sind and the adjoining areas in North-West India during the South-West monsoon. Over the rest of the country the correlations increase slightly during clear weather and decrease during the wet months.

4. Factors controlling the inter-monthly correlations of maximum temperature.—From the preceding section it will be evident that high inter-monthly correlations of maximum temperature usually occur during dry months and that the centres of high correlations lie over areas where the weather is com-

paratively dry. As mentioned in an earlier investigation ([1]), it is only during periods of settled weather that the accumulation of heat and the consequent " carry over " of this factor from one month to another can take place in an uninterrupted manner. Without such a process taking place it is difficult to see why adjacent months during certain seasons and in certain areas should be highly associated, the fact that, with the incidence of high winds and wet weather, this association breaks down, lends further support to the above conclusion.

The ideal condition for the high association of the climate of neighbouring months will be the persistence of:

(1) Clear skies,

(2) Feeble air movement,

(3) Absence of clouds and precipitation.

Under these conditions insolation has full sway and the accumulation of heat is localised

From a comparison of *Figures 1 to 12* with the climatological maps showing the mean maximum temperature, wind, cloudiness and rainfalls* one finds that areas of " minimum or no cloudiness ", minimum air movement, minimum rainfall and highest maximum temperatures do not coincide in all months and that it is not possible to establish perfect agreement in phase between the movements of the area of high correlation with that of a region where all the favourable conditions coincide.

The best agreement in phase is obtained with the movements of the sub-tropical belt of high pressure which exists at the upper levels between 2 and 4 Km This high pressure area lies over North-West India during the monsoon period and moves southward as the monsoon retreats, remaining over South India during winter and resuming its northward march as the summer advances and the monsoon sets in again

The high pressure area which coincides with the area of maximum correlation exists at about 4 Km level over South India during winter and at about 2 Km level over North-West India during the monsoon. The high pressure area is also the region of feeble winds as is usually the case over an anticyclone†. *Figures 13, 14, 15 and 16* show roughly the areas of highest maximum temperature and minimum cloudiness along with the high pressure area and the area of maximum correlations during August-September, September-October, November-December and January-February. These figures illustrate the southward movement of the area of high correlations and the associated weather elements from North-West India to South India.

In conclusion the author wishes to express his thanks to Dr. K. R. Ramanathan for making available the upper air wind data and also for his useful suggestions. Thanks are also due to Dr. L. A. Ramdas for suggesting the problem and for his help in the preparation of this note. The author also gratefully acknowledges the help of Mr. Ananthapadmanabha Rao and of the Statistical Section of the Agricultural Meteorology Branch in the computation of some of the correlation coefficients

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* Eliot's Climatological Atlas of India

† Winds have been taken as ' feeble ' when the velocity did not exceed 5 metres per second at 4 Km. and 3 metres per second at 2 Km.

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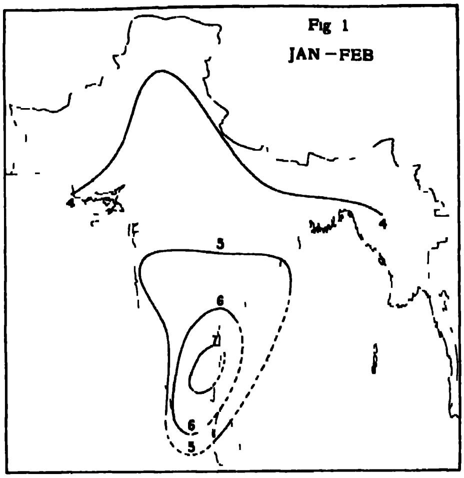

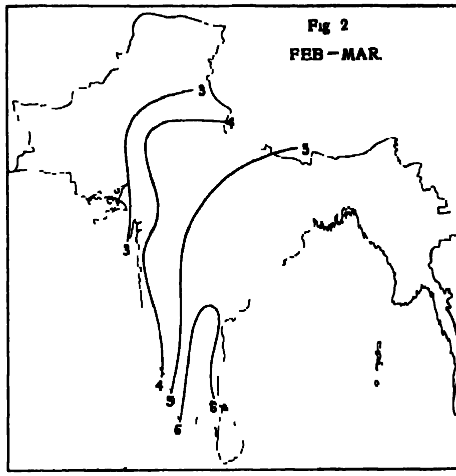

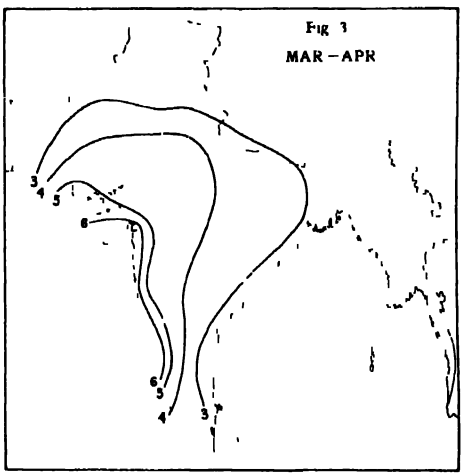

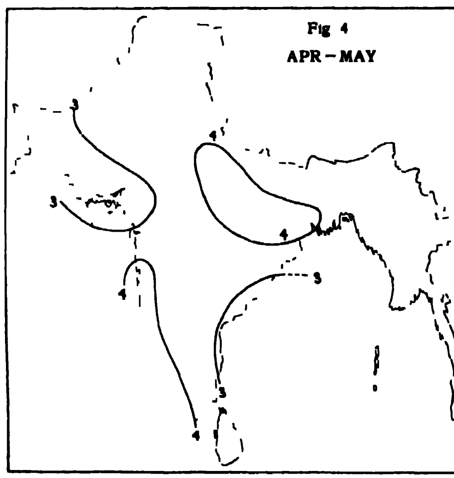

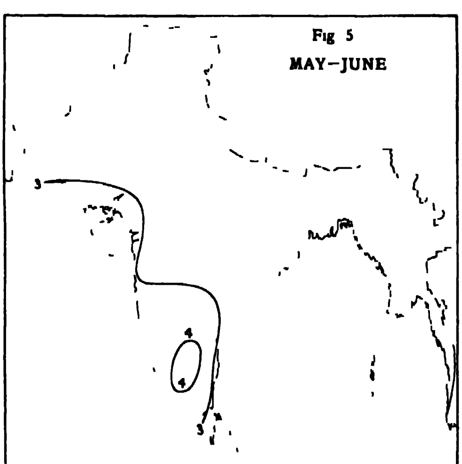

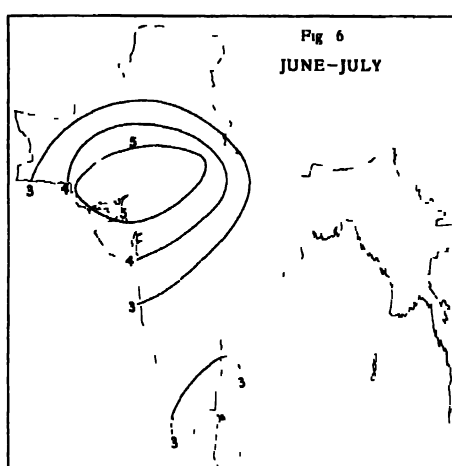

MEAN MAXIMUM TEMPERATURE CORRELATION MAPS

G P Z O POONA 1936

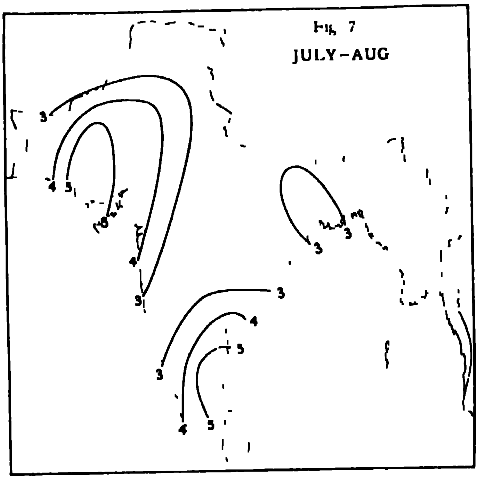

Fig. 7
JULY-AUG

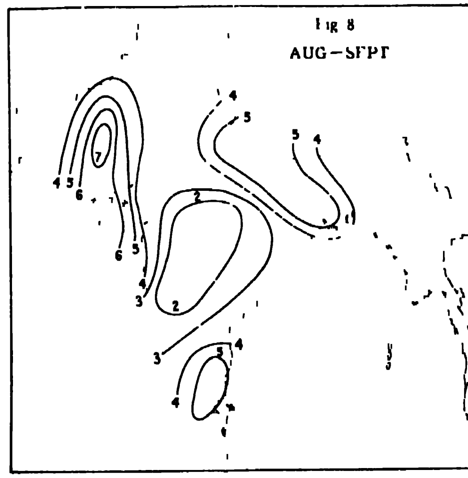

Fig 8
AUG-SEPT

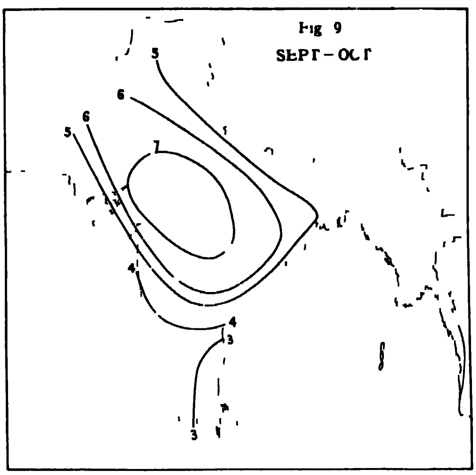

Fig 9
SEPT-OCT

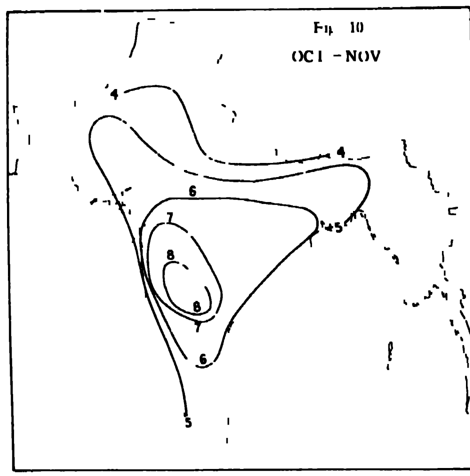

Fig 10
OCT-NOV

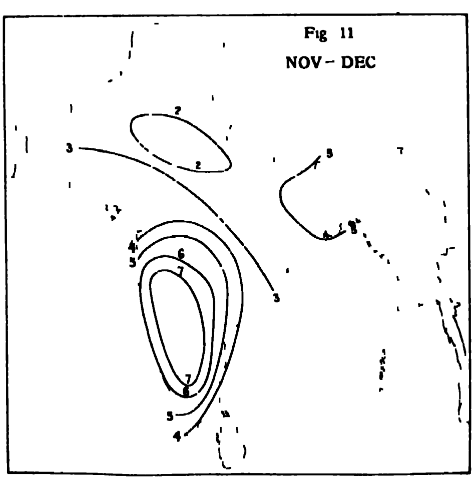

Fig 11
NOV-DEC

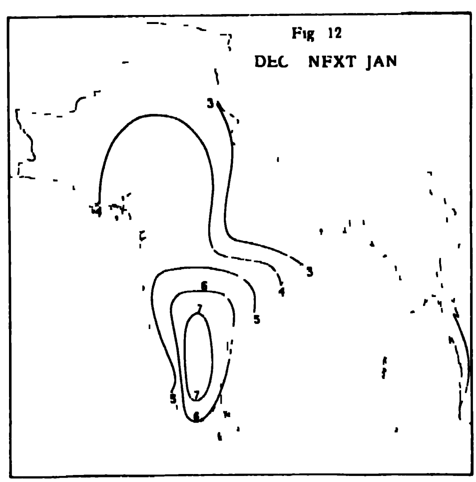

Fig 12
DEC NEXT JAN

MEAN MAXIMUM TEMPERATURE CORRELATION MAPS

G P Z O POONA 1936

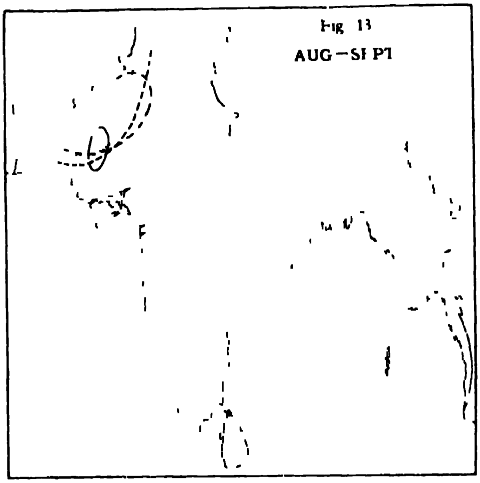

Fig 13
AUG – SEPT

Area of Minimum Cloudiness (cloud amount 2 or less than 2)
——— Area of High Correlation Centre (and above)
- - - (Area of Low winds (3 metres per second or lower at 2 km above mean sea level over North West India and 5 metres per second or lower at 1 km above mean sea level over South India)
- –Area of High Mean Maximum Temperature (100°F and above)

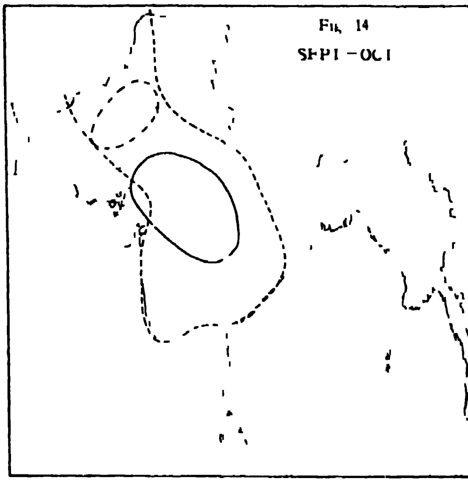

Fig 14
SEPT – OCT

Area of Minimum Cloudiness (cloud amount 1 or less than 1)
——— Area of High Correlation Centre (and above)
(Area of Low winds (3 metres per second or lower at 2 km above mean sea level over North West India and 5 metres per second or lower at 1 km above mean sea level over South India)
–Area of High Mean Maximum Temperature (100°F and above)

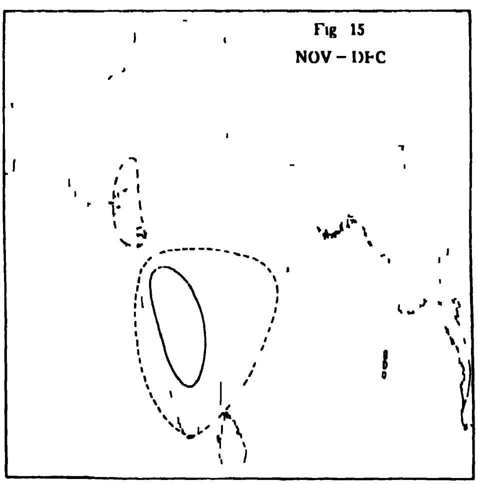

Fig 15
NOV – DEC

Area of Minimum Cloudiness (cloud amount 1 or less than 1)
- ——— Area of High Correlation Centre (7 and above)
- (Area of Low winds (3 metres per second or lower at 2 km above mean sea level over North West India and 5 metres per second or lower at 1 km above mean sea level over South India)
Area of High Mean Maximum Temperature (90°F and above)

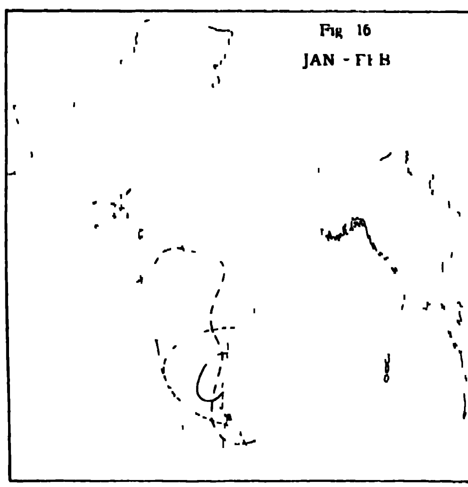

Fig 16
JAN – FEB

Area of Minimum Cloudiness (cloud amount 1 or less than 1)
- - - - Area of High Correlation Centre (7 and above)
- - - - (Area of Low winds (3 metres per Second or lower at 2 km above mean sea level over North West India and 5 metres per second or lower at 1 km above mean sea level over South India)
Area of High Mean Maximum Temperature (85°F and above)

MEAN MAXIMUM TEMPERATURE CORRELATION MAPS

NO—SN7/69

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A Statistical Analysis of the Distribution of the South-West Monsoon Rainfall at Akola.

BY

V. SATAKOPAN, M.A., Agricultural Meteorology Branch.

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A STATISTICAL ANALYSIS OF THE DISTRIBUTION OF THE SOUTH-WEST MONSOON RAINFALL AT AKOLA.

BY

V. SATAKOPAN, M.A., *Agricultural Meteorology Branch.*

(*Received on 10th September 1935.*)

Abstract.—The paper contains a discussion on the distribution of the south-west monsoon rainfall at Akola. The distribution of rainfall in each season of 155 days (consisting of 31 five day periods) from May 22nd to October 23rd is represented by a set of six distribution constants obtained by the method of fitting orthogonal polynomials. The series of distribution constants thus obtained are examined for secular changes. It is found that the average rainfall for the last 60 days of the season during the period 1889-1913 was slightly deficient in comparison with previous and later years. The relationships among the distribution constants themselves are also discussed.

1. Introduction. In studies on rainfall in relation to crop yields, a consideration of the distribution of rainfall during a wet season is, perhaps, more essential than merely the total rainfall during the period. The present note deals with an analysis of the south-west monsoon rainfall at Akola (20° 42′ N 77° 2′ E) which is an important centre of the cotton growing tract of Berar. The average annual rainfall of the station is 30.73 inches, most of the rain being received during the south-west monsoon season, June–October. For the purpose of this investigation the period of south-west monsoon rainfall has been taken to be from May 22nd to October 23rd, consisting of 155 days. Rainfall during the rest of the year at Akola is mostly associated with pre-monsoon or post-monsoon thundershowers and south moving depressions in the winter months. *Table 1* (given at the end of the note) shows the rainfall amounts for each of the years from 1868–1932 during the monsoon period and during the rest of the year.

The monsoon season of 155 days is divided into 31 periods of five days each and the rainfall for each five day period is computed from the daily rainfall records for the different years. The unit of time consisting of 5 days although arbitrary is sufficiently small to represent the rainfall distribution in the season. The distribution of rainfall for each season is represented by a set of six constants a', b', c'

etc. which are proportional respectively to A, B, C etc. of the orthogonal polynomial of the 5th degree,

$$y=A+Bf_1(t)+Cf_2(t)+Df_3(t)+Ef_4(t)+Ff_5(t)$$

fitted to the series of 31 five-day rainfalls, the functions $f_1(t)$, $f_2(t)$ etc. in the above being as developed by Fisher (1). *Table 2* (given at the end) shows the values of these constants for each of the 65 years from 1868 to 1932. These form the basis of our study in this paper.

2. **The Average Distribution.**—The average distribution of rainfall during the 65 years under investigation is represented by the mean values of the distribution constants that are given at the end of *Table 2*. The equation of the curve of this average distribution as derived from these mean values of constants is:

$$r=904\cdot28-7\cdot64t-5\cdot0276\ (t^2-80)+\cdot2069\ (t^3-143\cdot8t)-$$
$$\cdot021264\ (t^4-205t^2+4896)-\ \cdot001718\ (t^5-265t^3+13524t),$$

in the form of orthogonal polynomials which can be reduced to the ordinary form :—

$$r=1200-60\cdot6t\ \ -0\cdot669t^2+0\cdot662t^3-0\cdot0213t^4\ -\cdot00172t^5.$$

In the above equations the value of t varies by unity from —15 to +15, being measured from the mid-point of the season, and r represents the rainfall in thousandths of an inch falling in the t^{th} five-day period.

The actual curve of this distribution is plotted in *Fig. 1.* The figure gives also in the form of a histogram the average value of the daily rainfall amount for each five-day period. The curve indicates that the rainfall of the average season begins by the end of May and increases at a quick rate till about July 15th and then begins to decrease at a slower rate than the rate of increase. The decrease goes on till about the third week of August and then the rainfall has a tendency to be steady for a short time. It is during this period that some years have a second maximum though this is not usually as high as the first. The secondary maximum is to a certain extent reflected in the histogram referred to above. The rainfall again decreases rapidly with the beginning of October and the rains ultimately cease by the middle of the month. These are the average characteristics of the distribution of the south-west monsoon rainfall at Akola.

This average distribution appears to have a very high order of variability as seen from the values of the coefficients of variability of the distribution constants given in *Table 3* below.

TABLE 3.

Variability of the distribution constants (unit=one thousandth of an inch.)

——	a'	b'	c'	d'	e'	f'
Mean	904·3	—38 2	—145 8	36 0	—22·2	—10·6
S. D.	305·3	105·9	73 3	66 3	47·7	43·8
Coefficient of Variation ..	33·8	277·2	50 3	184·2	214·9	413·2
S.D. / $\sqrt{65}$	37·9	13·1	9·1	8·2	5·9	5·4

The coefficients of variability for all the constants are very high showing thereby that the type of distribution on the whole is subject to large deviations from the average in different years.

Judged from their standard errors given in the last row of the above table, all the means of the constants are significantly different from zero except f' which is just on the verge of significance, showing thereby that the effects indicated by the constants in the average distribution are real.

3. **Slow Changes in the Constants.**—The next problem is to examine how the high variability in the distribution as found in the last section occurs. Does this variability include any systematic change in the distribution or is it wholly composed of variations from year to year in a random manner? Any systematic law of variation if it exists should be reflected in the form of secular changes in the series of the distribution constants. Considering the six series of distribution constants as six time series with a unit of one year for t, they were subjected to further analysis by fitting polynomials.

Now each series of distribution constant consists of 65 values and the progressive sums up to S_6 have to be determined. The series have been split up into two portions of 33 and 32 values and the respective progressive sums determined for each portion separately. If the progressive sums of the first 33 values are denoted by s_1, s_2, s_3 etc. and those of the 32 values as s'_1, s'_2, s'_3, s'_6 then S_1, S_2,........ S_6, which are the progressive sums for the whole series are obtained by utilising the following relations :—

$$S_1 = s_1 + s'_1$$

$$S_2 = ns_1 + s_2 + s'_2$$

$$S_3 = \frac{n(n+1)}{2} s_1 + n\, s_2 + s_3 + s'_3$$

$$S_4 = \frac{n(n+1)\,(n+2)}{2 \cdot 3} s_1 + \frac{n(n+1)}{2} s_2 + n\, s_3 + s_4 + s'_4$$

$$S_5 = \frac{n(n+1)\;\;(n+3)}{2 \cdot 3 \cdot 4} s_1 + \frac{n(n+1)\,(n+2)}{2 \cdot 3} s_2 + \frac{n(n+1)}{2} s_3 + n\, s_4 + s_5 + s_5'$$

$$S_6 = \frac{n(n+1).\;(n+4)}{2 \cdot 3 \cdot 4 \cdot 5} s_1 + \frac{n(n+1)\;\;(n+3)}{2 \cdot 3 \cdot 4} s_2 + \frac{n(n+1)\,(n+2)}{2 \cdot 3} s_3 + \frac{n(n+1)}{2} s_4 + n\, s_5 + s_6 + s'_6$$

where $n = 32$ (the number of observations in the latter portion of the series.)

These formulæ of combinations for finding the progressive sums for a long series are found to be simpler than those given by Fisher ([1], p. 111), where the latter part of the series is summed from bottom upwards omitting the last figure in each successive summation and the combination is effected in two stages. These equations may also be utilised to find any one of the three sets of sums (1) S_1, S_2, etc., (2) s_1, s_2, etc., (3) s'_1, s'_2, etc., provided the values of the other two sets are known. This fact may be found useful in dealing with such progressive sums.

The distribution constants for the six series were determined from S_1, S_2, etc., and for each series the nature of slow changes, if any, is found from these constants. To test the significance of these slow changes it is necessary to evaluate the variances contributed by each degree of the curve fitted, to compare them individually and

collectively with the residual variance. These variances are got from the constants b', c', d', e' and f' of the series by multiplying their squares by the factor:

$$\frac{(2r+1)\, n\, (n+1) \; .. \; (n+r)}{(n-1) \quad . \quad . \quad . \quad (n-r)}, \text{ putting } r = 1, 2, 3, 4, 5,$$

according to the degree of the term. The resulting quantities are denoted by x'^2_2 x'^2_3, etc., and these represent the sums of squares contributed by the various degrees of the curve. Their sum when deducted from the sum of squares of deviations from the mean will give the residual sum of squares. The residual variance is obtained by dividing this by the number of degrees of freedom *i.e.* n—r—1, where n is the number of observations in the series and r, the degree of the curve fitted. The values of x'^2_2, x'^2_3, etc., are individually comparable with this residual variance and by the z test the significance of these variances can be tested, and the nature of the slow changes ascertained. Collectively also, the sum of the quantities x'^2_2, x'^2_3 etc. gives the sum of squares contributed by the curve fitted and as such the total variance contributed by a 5th degree curve is given by $\frac{x'^2_2 + x'^2_3 \; .. \; x'^2_6}{5}$; this is compared with the residual variance and the significance tested.

While the individual significant values of x'^2_2 etc. indicate the nature of the secular changes along particular directions, the existence of these changes is not taken to be definitely established unless the variance is significant in the collective test also.

As a result of such analysis, it was found that none of the six series of the distribution constants of Akola rainfall showed any significant effect under the collective test, though individual values of the x's were found to be just significant in some cases.

The results of the above analysis are given in a slightly different form in *Table 4* for easy comparison. The square roots of the variances with the signs of the respective distribution constants attached to them are given with the square root of the residual variance which is called the "*standard residue*". Any value of x'_2, x'_3, etc., that is greater than twice the standard residue can be considered significant. From the table it can be easily seen that the collective variance is not significant in any of the series.

TABLE 4.

Slow changes in distribution constants (unit=one thousandth of an inch.)

	a'	b'	c'	d'	e'	f'
Mean	904·3	—38 2	—145 8	36·0	—22·2	—10·6
x'_2	—429·0	16·1	3·7	—31·2	7·2	0·6
x'_3	—63·9	182·4	143·2	—120·0	—115·0	39·2
x'_4	562·4	216 3	8 0	50·5	—36·4	—53·6
x'_5	—99·9	—33·1	—132·1	—18·6	76·8	—15·9
x'_6	—153·1	34·0	—18·1	—54·9	—38·0	47·4
Standard Residue	303·3	103·8	72 0	66·4	45·8	44·3

Taking the series a', none of the values of x's require any remarks except x'_4, which though not significant is on the verge of it. This shows a trace of change

along a cubic curve. The polynomial values with the ten-year moving average values for this series are plotted in *Figure 3(a')*. It is seen that this trace of change is because of a series of wet years about 1875 to 1895. However, the change is small when compared with the S. D.*

Coming to series *b'*, the values of x'_3, and x'_4 deserve some mention. x'_3, is not significant but fairly high, and the value of x'_4 is seen to be significant. From *Figure 3 (b')* it is seen that *b'* has decreased from high values at the beginning, and towards end of the period in question it shows signs of increasing quickly ; but when compared with the total variation this factor is not in any way considerable since the standard error is reduced from 105·9 to only 102·2, when the third degree is fitted.

Taking *c'*, only x'_3 is on the verge of significance and *Fig.* 3(*c'*) indicates that this is because of a series of low values of *c'* from about 1890 to 1913.

The series of *d'* shows no trend worth mentioning.

The value of x'_3 for series *e'* is greater than twice its standard residue and hence is significant. This indicates a parabolic change in the series. *Figure 3(e')* indicates generally higher values of *e'* during the period 1890 to 1913.

The constant *f'* shows no secular changes.

From the above remarks it is evident that although no significant slow changes are observed in the distribution constants on the whole, the significant values of some of the x's indicate some changes, the effect of which may be examined further. A comparative study of the curves in *Figure 3* shows that the deviations of the three constants *b'*, *c'* and *e'* from their average values during the period 1890-1913 require explanation.

To see whether this correspondence in the variation of average values is associated with any significant change in the average distribution, the whole period of 65 years was divided into three divisions as follows :—

I	..	1868 to 1888	21 years.
II	.	1889 to 1913	25 years.
III	..	1914 to 1932	19 years.

The average values of the distribution constants with their standard errors for the corresponding periods are given in *Table 5* below.

TABLE 5.

Average distributions (unit=one thousandth of an inch.)

—	I, 1868—1888 21 years		II, 1889—1913 25 years.		III, 1914—1932 19 years	
	Mean.	S D.	Mean.	S. D.	Mean.	S D.
a'	993 76	401·62	875 12	248·64	843 74	235·26
b'	—23·19	110·87	— 67·68	83·20	— 15·89	122·50
c'	—131·10	42·79	—175·88	79·13	—122·47	81·62
d'	43·00	83·93	43·52	48·73	18·53	64·64
e'	— 36·90	38 02	— 2·12	43·70	— 32·42	54·85
f'	— 10·38	54·80	— 13·58	38·26	— 7·05	38·95

* In this connection a reference is invited to Blanford's discussion of a similar but more pronounced increase in rainfall in Central Provinces area which he ascribes partially to the forest policy in the area concerned. (3. P. 136—140).

On examining the above table the following differences in the averages of the various distribution constants are observed:—

(1) a' of I is higher than that of II and III.

(2) d' of III is lower than that of I and II.

(3) b', c' and e' of period II show differences from their values for other periods.

The differences in the mean values noted above were tested by comparing them with their respective standard errors calculated from the pooled estimates of variances. In the cases of (1) and (2) the differences were not found to be significant, whereas in (3) the two constants c' and e' showed significant differences. This indicates that the average distribution over the period II has been different from that over the remaining periods, so far as the changes in the constants c' and e' are concerned.

The average distribution of rainfall over these three periods are shown separately in *Figure 2*, by curves 1, 2 and 3. It is seen that the curves 1 and 3 are similar in shape except for a difference in the total rainfall which has been found to be not significant as already stated. The average distribution for period II is of a different type showing deficient rainfall towards the latter part of the season as compared with the other two periods. The rainfall for the last sixty days of the rainy season (corresponding to twelve five-day periods) shows the following results:—

	Mean rainfall in inches (August 25th to October 23rd)	S. D.
Period I	11·23	7·95
Period II	7·12	3·63
Period III	9·26	5·89

The mean rainfall over I and III is 10·30″, which is 3·18″ higher than in II. The pooled estimate of S. D. for this difference having 63 degrees of freedom=1·52.

$$\therefore \quad t = \frac{3\cdot18}{1\cdot52} = 2\cdot09$$

Hence it is found that the rainfall for this period of 60 days during the years 1889—1913 has been on the whole deficient when compared with the rainfall of the corresponding period for previous and later years.

Summing up, though traces of slow changes of the distribution are observed from an analysis of the distribution constants, the average type of the distribution has not been materially altered except for the fact that during the 25 years 1889—1913, the rainfall for the two months from about 20th August to 20th of October has been less than in previous and later years by about 3 inches.

4. **Correlation in the Distribution Constants.**—We have chosen a set of six mutually independent functions of time in arriving at the values of a', b', etc., to represent the distribution of the rainfall of any one year. Therefore, if the incidence of rainfall in one period of a season is not related to that of any other period there will be no relation between the distribution constants. On the other hand if it were found that the distribution constants are related, it can be said that the distribution

of rainfall between various parts of the season are not totally unrelated. In *Table 6* are given the correlation co-efficients between the series of the distribution constants.

TABLE 6.

	a'	b'	c'	d'	e'
b'	·2734				
c'	—·4342	·0337			
d'	·2935	—·5260	—·1889		
e'	—·0953	—·1862	—·5397	—·0073	
f'	—·1119	—·0458	·1708	—·4539	·0972

From Fishers' *Table V-A*, (2) the 5% value of correlation coefficient for n=63 is ·2464 and hence any C. C. higher than this can be taken to be significant. Judging from this, six correlation coefficients are seen to be significant. However on applying Walker's criteria (4) for a set of 15 correlation coefficients, the 5% random value for the highest coefficient in table 6 is ·3563 and on this basis it is found that only four of the c. c's are significant. Before we examine what these relationships indicate, it is necessary to see whether the traces of slow changes observed in *Section 3*, have any part to play in these correlations. The correlations after removing the effect of these slow changes can be obtained as follows. From the sum of products of deviations for any two series, the products of corresponding x's given in *Table 4* are subtracted and the remainder can be termed the residual sum of products. This is divided by the number of degrees of freedom (59 here) and also the product of the standard residues of the two series. This gives the correlation coefficient after eliminating the effects of the slow changes. *Table 7* gives these correlation coefficients.

TABLE 7.

	a'	b'	c'	d'	e'
b'	·2503				
c'	— 4905	—·0338			
d'	·2698	—·5500	—·1608		
e'	—·0863	—·1147	—·4867	—·0638	
f'	—·0721	—·0416	·1524	—·4299	·1551

These represent the correlation coefficients of the distribution constants after eliminating the slow changes up to the 5th degree. For n=58, the 5% value of C. C. from *Table V-A* of Fisher (2) is ·2546 and ·3614 for Walker's test and it is seen that the order of the correlation coefficients are not altered and so we conclude that the slow changes in the distribution constants have nothing to do with these correlations

between the distribution constants and hence the relationships indicated by the correlation coefficients above arise out of the variations of the constants in the individual years.

5. The nature of the internal relationships in the distribution.—In order that we may know the nature of the relationship arising out of these correlations shown in *Table 7*, it is necessary to know also the nature of variation in the distribution for variations in the constants.

a', as we know, is proportional to the total amount of rain and hence, while other distribution constants remain the same an increase or decrease in the value of a' will simply increase or decrease the area of the curve of distribution without changing its shape ; we know also that b' being the constant that measures the straight line effect in the distribution, is proportional to the gradient of the straight line fitted to the distribution. A negative value in b' will indicate a decreasing tendency in the distribution whereas a positive value will show a uniform increase in the distribution. The relationships of the remaining constants to the distribution are more and more complicated and we know only that each one of them is bound up with one degree of the curve of distribution.

To get a rough idea as to the change in the shape of the distribution corresponding to a variation in the other distribution constants, the following procedure was adopted. Taking a standard set of distribution constants, and knowing the shape of that distribution, we can alter one of the constants and contrast the shape of the resulting curve with that of the original curve. The change in the shape between the two curves is then a direct result of the change that we have made in the particular distribution constant, since the other constants are independent of this variation.

The average distribution of *Fig. 1* was taken to be our standard for this purpose and constants b', c', d', e' and f' were given two extreme values, one on either side of the average, in each case all the other constants remaining same as for the standard. *Figures 4 to 8* give these sets of curves.

One peculiar feature in this process is that all the curves arising out of varying one constant only, will pass through a certain number of points fixed on the standard curve depending upon the constant changed. These points are fixed whatever may be the value of the distribution constant under consideration. The abscissæ of such points are given by equating the various orthogonal functions of t to zero in the equation of the average distribution given in *Section 3*. For instance all the curves that are formed from the variations in c', keeping the other constants same will pass through the points whose abscissæ are given by $(t^2—80)=0$, (see *Fig. 5*) ; because, for this value the term vanishes and as such the resulting value of r does not depend upon this variable term. This gives two points through which all the curves for varying c' pass. The curve is divided into three portions and the changes in the distribution curve for changes of c' can be divided into three sections. For instance the fixed points on this curve are $t = \pm 8{\cdot}9$, say about ± 9. Therefore the changes in c' alter the distribution curve in three sections, (1) $t = —15$ to $—9$, (2) $t = —9$ to $+9$, (3) $t = +9$ to $+15$. In the first section the change does not seem to be material. As c' varies from a high negative value to zero the distribution curve in Section 1 goes slightly higher covering more area. The second section which covers nearly 2/3 of the whole period shows a tendency to develop a minimum as the value of c' gets nearer zero. The third section develops a maximum as c' gets nearer zero. Of course it is theoretically possible to find the value of c' for which the minimum and maximum of sections 2 and 3 above in this case develop, but it may not be of much interest to us as it depends on the other constants also. By studying such curves given in *Figures 4 to 8*, a general idea can be had of the relation between the constants and the shape of the distribution for the required range of variation.

Now turning our attention to *Table 7* we shall see what the significant correlations indicated therein mean. It is however not possible to assert anything with regard to these correlation coefficients but when these correlations are studied with the help of *Figures 4 to 8*, they are suggestive of some relations which are indicated below.

We find that the constant a' is related to b' and d' and significantly so with c', indicating thereby that the general distribution of rain in a season is dependent on the total rainfall received. The correlation between a' and c' indicates that wet years have more concentrated rainfall from about the 20th June to 20th September and that comparatively drier years seem to have a distribution approximating to curve III of *Fig. 5.* The correlations of a' with b' and d', though comparatively small, are still significant. It may be noted that though b' and d' are positively related to a', the relation between themselves is highly negative and hence the two are complimentary in their relation to a', *i.e.* (1) when a' and b' change alike a' has no effect on d', whereas when a' and d' change alike a' has no effect on b'. This is indicated by *Tables 8-a* and *8-b* where instances are given to which many more can be added, of these two types of relations. It may be noted that the partial correlations between a' and b', and a' and d' are enhanced if the relation of b' and d' is eliminated.

$$r_{a'b'f} = +\cdot 4959\,;\; r_{a'd'b'} = +\cdot 5040.$$

The correlation between c' and e' seems to indicate that high negative values of c' gives in general a distribution with a single maximum as seen from comparing curves in *Figures 5 and 7*, and, also that when values of c' are low, a distribution with a second maximum is likely.

The correlation between d' and f' indicates that high positive values of d' are associated with high negative values of f' and as such comparing the *Figures 6 and 8*, this relation would seem to mean that whenever d' is highly positive the chances of getting a second maximum are more.

In conclusion the author wishes to express his thanks to Dr. L. A. Ramdas, M.A., Ph D., and Dr. R. J. Kalamkar, B.Sc., B.Ag., Ph.D., for whose valuable suggestions and continued interest in this investigation he is grateful.

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TABLE 1.

Year.	Rainfall in inches between May 22nd and October 23rd.	Rainfall in inches during the rest of the year.
1868	21 27	3·03
1869	29·93	·23
1870	38·47	6 82
1871	13 75	4·36
1872	44·37	2 21
1873	22 69	1 35
1874	26·54	·14
1875	33 68	54
1876	18·61	0
1877	17·11	7·25
1878	42·09	·98
1879	25·59	·31
1880	15·70	3 70
1881	29·90	2 70
1882	25·95	2 18
1883	66 25	06
1884	41 28	7 62
1885	28 90	8 39
1886	34·65	2 03
1887	45·53	3·85
1888	24·70	3·25
1889	31·81	·60
1890	32·46	1 00
1891	29·59	3·87
1892	46·58	7·46
1893	27·28	9·16
1894	29·63	4·13
1895	25·01	2·03
1896	26 36	·79
1897	22·87	·51
898	20·14	·65
1899	10·65	1·43
1900	40·64	·08

TABLE 1—*contd.*

Year.	Rainfall in inches between May 22nd and October 23rd.	Rainfall in inches during the rest of the year.
1901	23·95	2·74
1902	24·47	2·98
1903	29·95	·75
1904	25·57	·43
1905	19 01	·18
1906	34·99	2·11
1907	19·21	3·39
1908	34·35	0
1909	24·29	7·02
1910	34·24	1·49
1911	19·32	3·15
1912	18·85	1·28
1913	26·94	·52
1914	26·64	2·20
1915	26·88	6·96
1916	41·34	4·31
1917	29·02	4·09
1918	12·34	2·58
1919	25·54	2·24
1920	10·47	1·55
1921	23·91	·30
1922	29·58	4·45
1923	21·92	1·64
1924	34·33	1·93
1925	19·29	3·89
1926	30·59	2·51
1927	28·28	5·11
1928	27·29	4·72
1929	21·10	3·20
1930	27·66	·87
1931	35·02	1·69
1932	25·73	2·52
Mean	28·03	2·70

TABLE 2. (*Distribution constants*).

(Unit=One thousandth of an inch.)

Years.	a'	b'	c'	d'	e'	f'
1868	686	— 146	— 110	+ 18	+ 18	+ 29
1869	965	+ 136	— 172	— 89	— 12	+ 6
1870	1241	— 200	— 199	+ 149	— 24	— 55
1871	444	— 63	— 53	+ 1	— 34	+ 23
1872	1431	+ 121	— 139	+ 41	— 139	— 87
1873	732	— 65	— 116	— 7	— 30	+ 24
1874 .. .	856	— 155	— 101	+ 57	— 81	+ 14
1875	1086	— 43	— 146	— 50	— 63	+ 73
1876 . . .	600	— 25	— 151	— 20	— 2	+ 45
1877	552	— 54	— 67	+ 47	— 55	+ 14
1878	1358	+ 243	— 184	— 19	— 41	— 65
1879	825	— 13	— 133	— 19	+ 14	— 21
1880	506	+ 54	— 40	— 35	— 22	+ 23
1881	965	— 101	— 143	+ 17	— 6	— 4
1882	837	— 108	— 116	+ 62	— 73	— 25
1883	2137	+ 46	— 100	+ 158	— 87	+ 94
1884	1332	+ 113	— 191	+ 71	— 9	— 27
1885	932	+ 20	— 127	+ 35	— 30	— 61
1886	1118	— 139	— 163	+ 167	+ 3	— 50
1887	1469	— 36	— 149	+ 267	— 56	— 140
1888	797	— 72	— 153	+ 52	— 46	— 28
1889	1026	+ 14	— 185	+ 90	+ 54	— 9
1890	1047	— 164	— 161	+ 117	— 26	— 71
1891	955	+ 168	— 145	— 18	— 80	— 115
1892	1503	— 65	— 280	+ 23	+ 13	+ 36
1893	880	— 90	— 23	— 79	+ 13	+ 62
1894	956	— 70	— 189	+ 63	— 43	— 44
1895	807	— 102	— 107	+ 73	— 43	— 35
1896	850	— 239	— 198	+ 127	+ 52	— 40
1897	738	+ 51	— 219	— 23	+ 39	— 18
1898	650	— 89	— 130	+ 51	— 9	— 13
1899	344	— 51	— 24	+ 1	— 47	+ 28

TABLE 2—*contd.*

Years.	a'	b'	c'	d'	e'	f'
1900	1311	— 13	— 396	— 8	+ 95	+ 23
1901	772	— 8	— 164	+ 50	+ 52	+ 17
1902	789	— 3	— 229	+ 16	+ 20	— 18
1903	906	— 75	— 201	+ 39	+ 56	— 88
1904	825	0	— 120	+ 24	— 45	+ 6
1905	613	— 20	— 138	+ 17	— 41	— 5
1906	1129	— 153	— 289	+ 97	+ 3	— 16
1907	620	— 122	— 157	+ 73	+ 19	— 4
1908	1108	— 170	— 249	+ 103	— 40	— 4
1909	784	— 96	— 142	+ 39	— 30	— 5
1910	1105	— 38	— 178	+ 5	— 58	+ 8
1911	623	— 129	— 109	+ 57	— 13	— 6
1912	608	— 95	— 154	+ 84	+ 6	— 29
1913	869	— 133	— 210	+ 67	0	+ 1
1914	859	— 15	— 143	— 27	— 72	+ 23
1915	867	— 18	— 177	+ 65	— 12	— 46
1916	1334	— 40	— 169	+ 51	+ 22	+ 30
1917	936	+ 46	— 38	— 45	— 48	— 4
1918	398	— 175	+ 15	+ 9	+ 3	— 7
1919	824	— 168	— 62	+ 60	— 68	— 1
1920	338	— 37	— 63	+ 27	— 25	— 3
1921	773	— 52	— 147	+ 9	— 24	+ 5
1922	954	— 135	— 240	+ 113	+ 3	— 72
1923	707	+ 60	— 139	— 11	— 45	— 5
1924	1107	+ 219	— 176	— 100	+ 8	+ 50
1925	622	— 88	— 119	+ 34	+ 38	— 1
1926	987	— 101	— 36	+ 89	+ 57	— 37
1927	912	+ 22	— 19	+ 47	— 164	— 70
1928	880	+ 56	— 30	0	— 76	+ 50
1929	681	— 209	— 67	+ 131	— 112	— 7
1930	892	+ 84	— 134	— 124	— 73	+ 41
1931	1130	+ 256	— 106	— 6	— 49	— 80
1932	830	— 7	— 207	+ 30	+ 21	0
Mean ..	904·3	—38·2	—145·8	+ 38·0	— 22·2	— 10·6

TABLE 8-A.

Year.	a′	b′	d′
1868	686	— 146	+ 18
1872	1431	+ 121	+ 41
1874	856	— 155	+ 57
1878	1358	+ 242	— 19
1884	1332	+ 113	+ 71
1888	797	— 72	+ 52
1918	398	— 175	+ 9
1925	622	— 88	+ 34
1931	1130	+ 256	— 6

TABLE 8-B.

Year.	a′	b′	d′
1870	1241	— 200	+ 149
1876	600	— 25	— 20
1879	825	— 13	— 19
1883	2137	+ 46	+ 158
1886	1118	— 139	+ 167
1887	1469	— 36	+ 267
1890	1047	— 164	+ 117
1908	1108	— 170	+ 103
1914	859	— 15	— 27

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Plate 1.

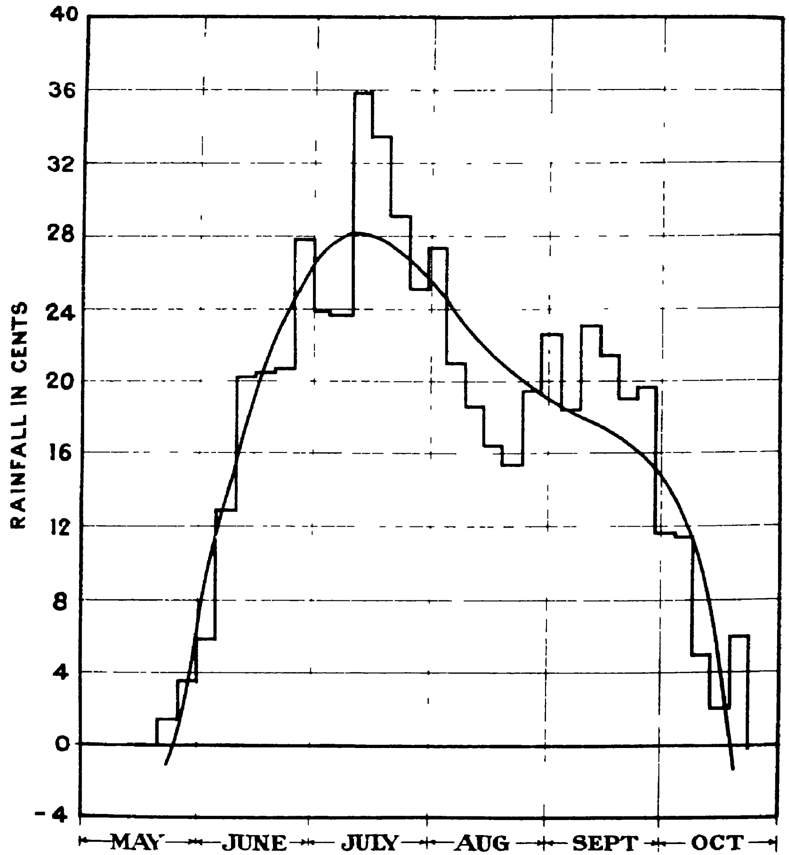

FIG 1 AKOLA RAINFALL — AVERAGE DISTRIBUTION
(1868-1932)

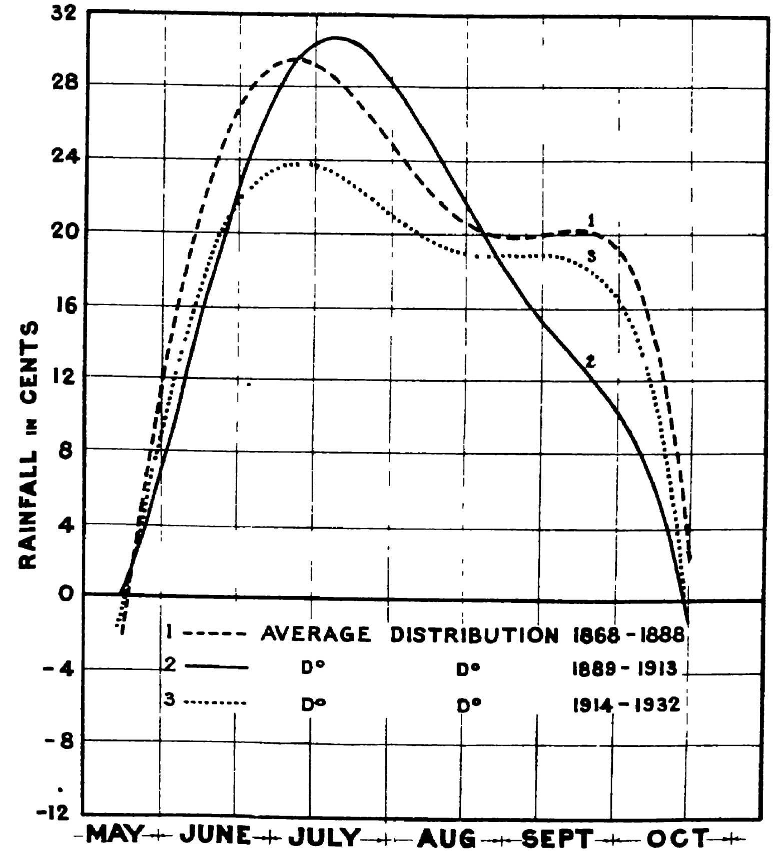

FIG 2 AKOLA RAINFALL — AVERAGE DISTRIBUTION
OVER SUB-PERIODS

G P Z O POONA 1936

Plate 2.

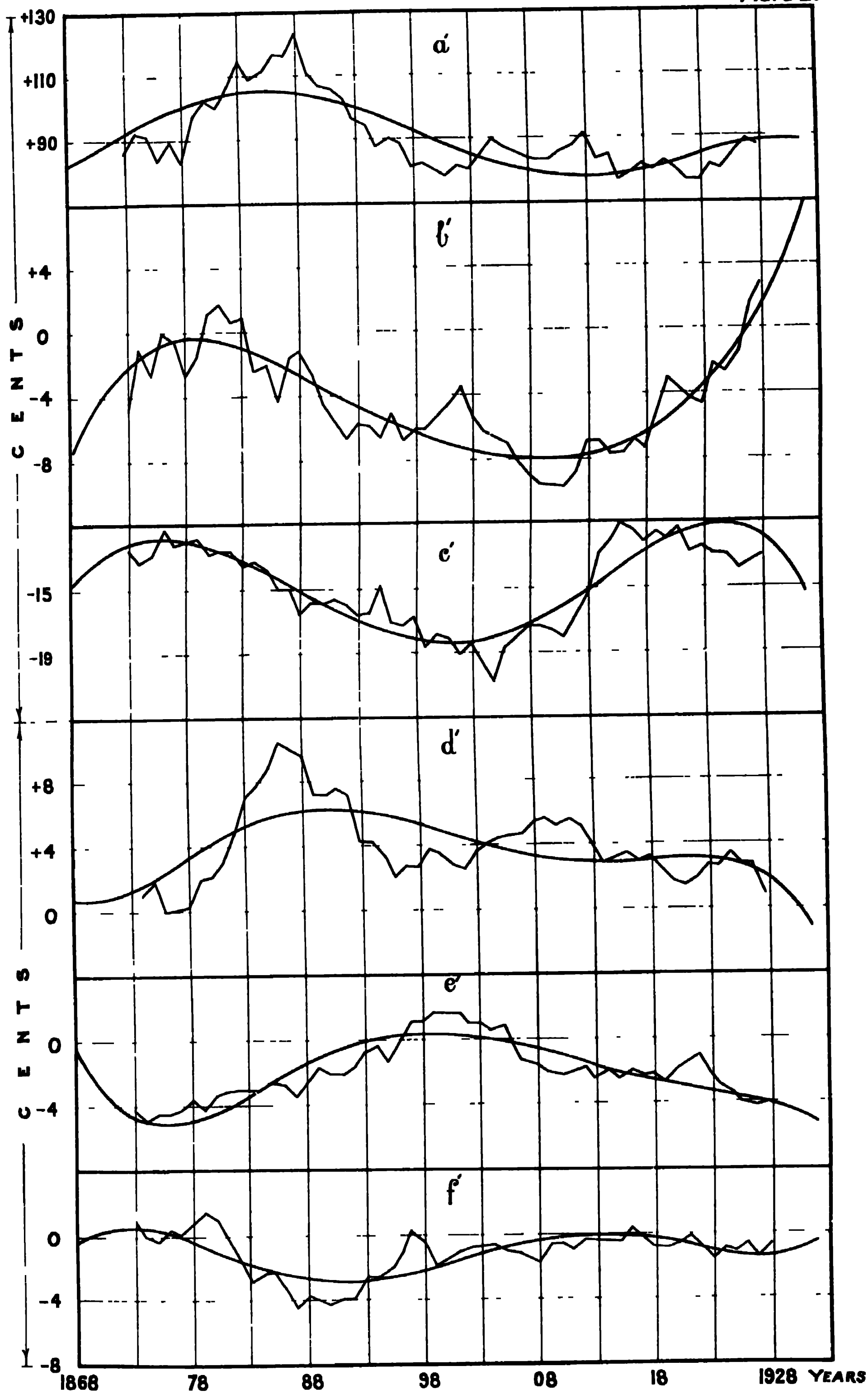

FIG 3 AKOLA RAINFALL — SLOW CHANGES IN THE DISTRIBUTION CONSTANTS.

Plate 3.

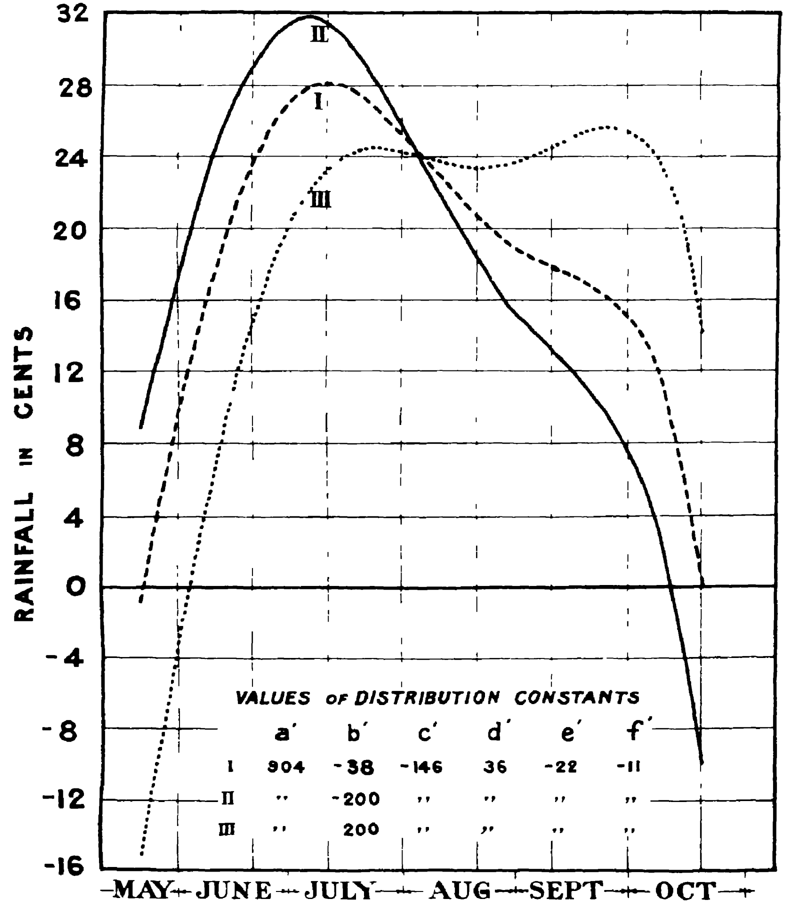

FIG 4 AKOLA RAINFALL— VARIATION IN b′

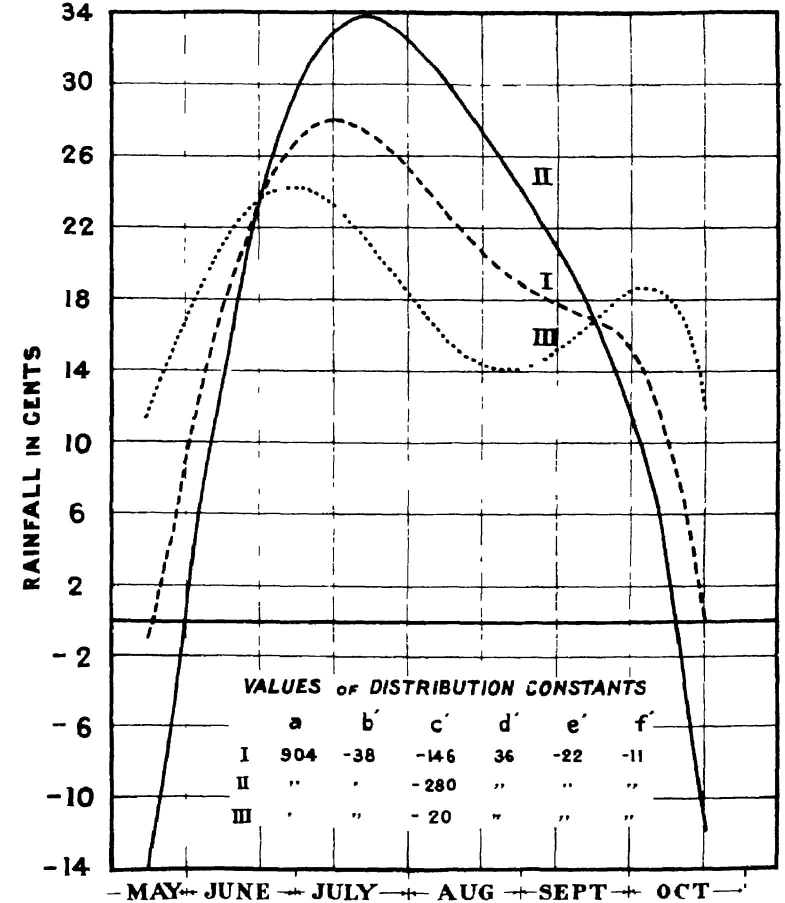

FIG 5 AKOLA RAINFALL— VARIATION IN c′

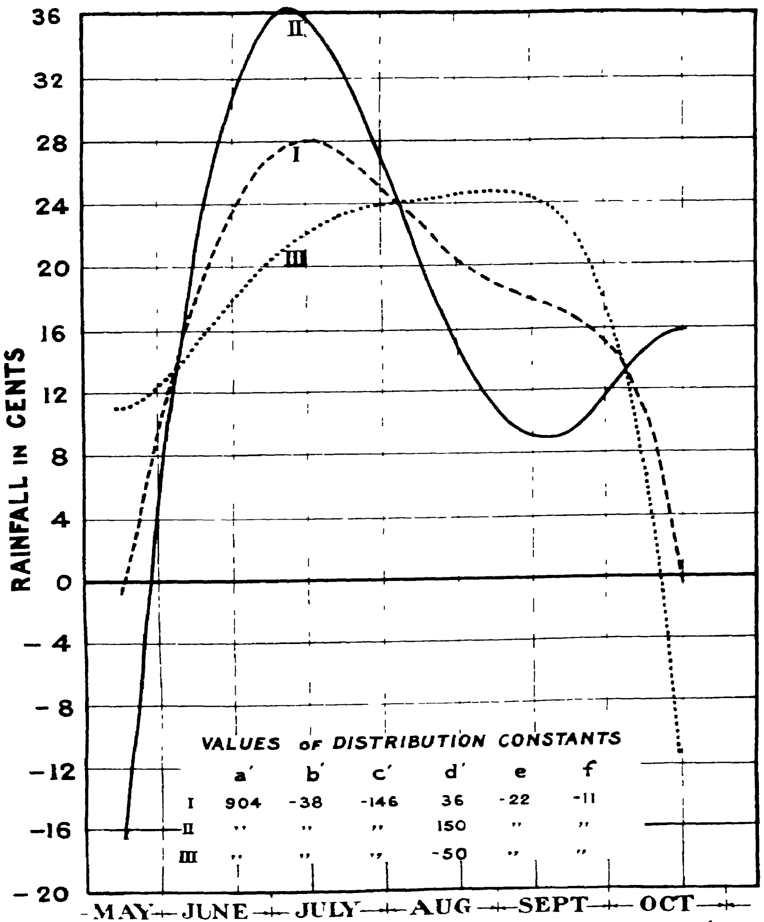

FIG 6 AKOLA RAINFALL – VARIATION IN d′

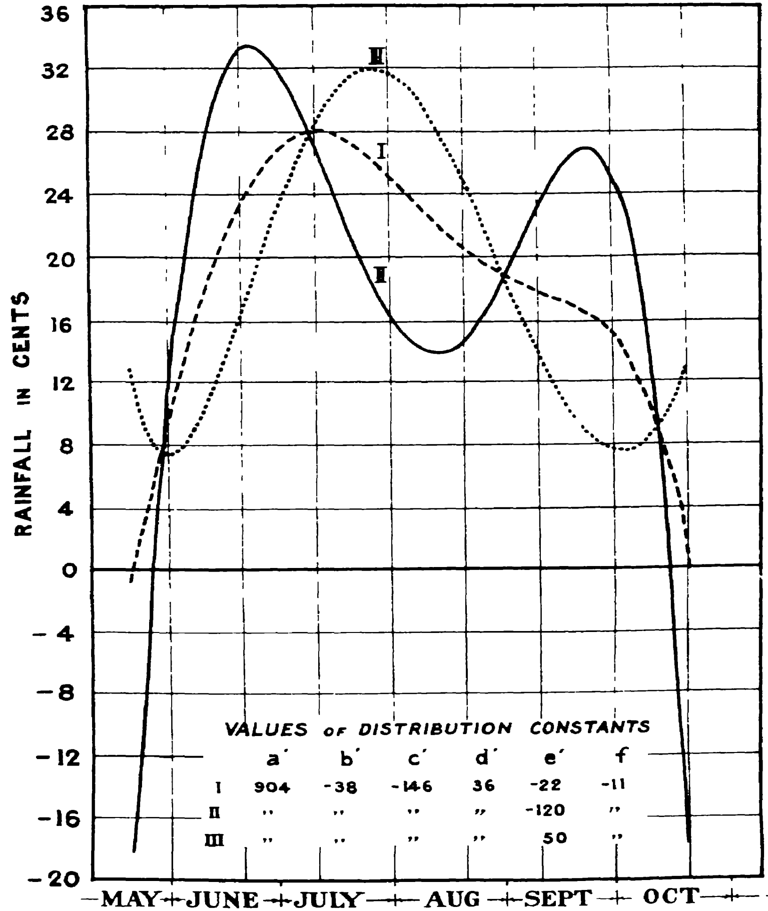

FIG 7 AKOLA RAINFALL – VARIATION IN e

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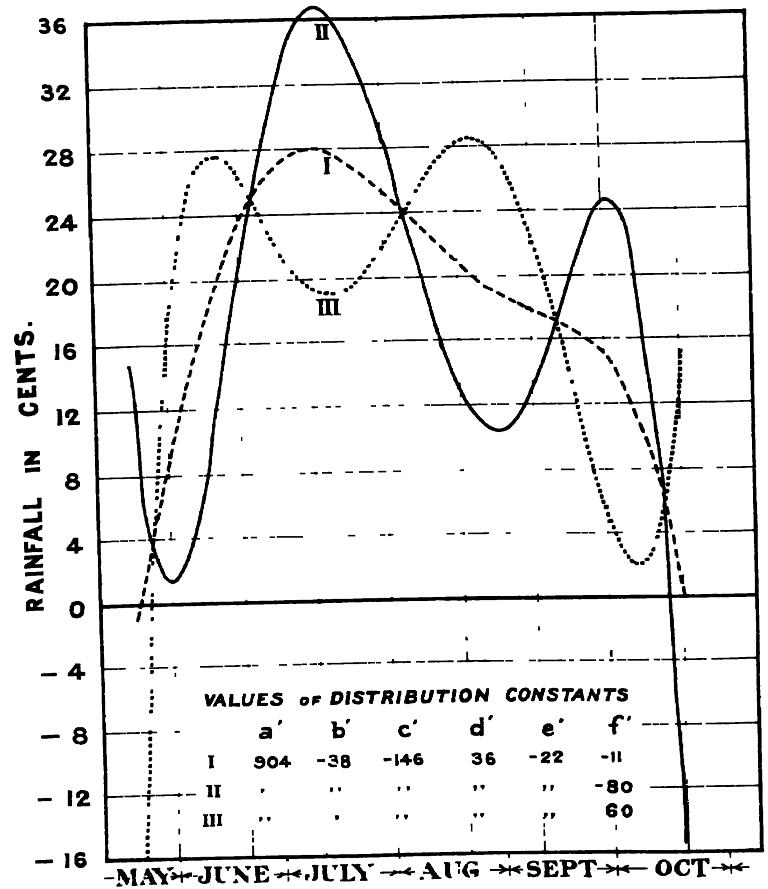

FIG 8 AKOLA RAINFALL — VARIATION IN f

G P J O POONA, 1938

NO—SN-6/68.

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. VI, No. 68.

Hourly Rainfall at Lahore

BY

V. DORAISWAMY IYER, B.A.

AND

V. LAKSHMINARASIMHAN, B.A.

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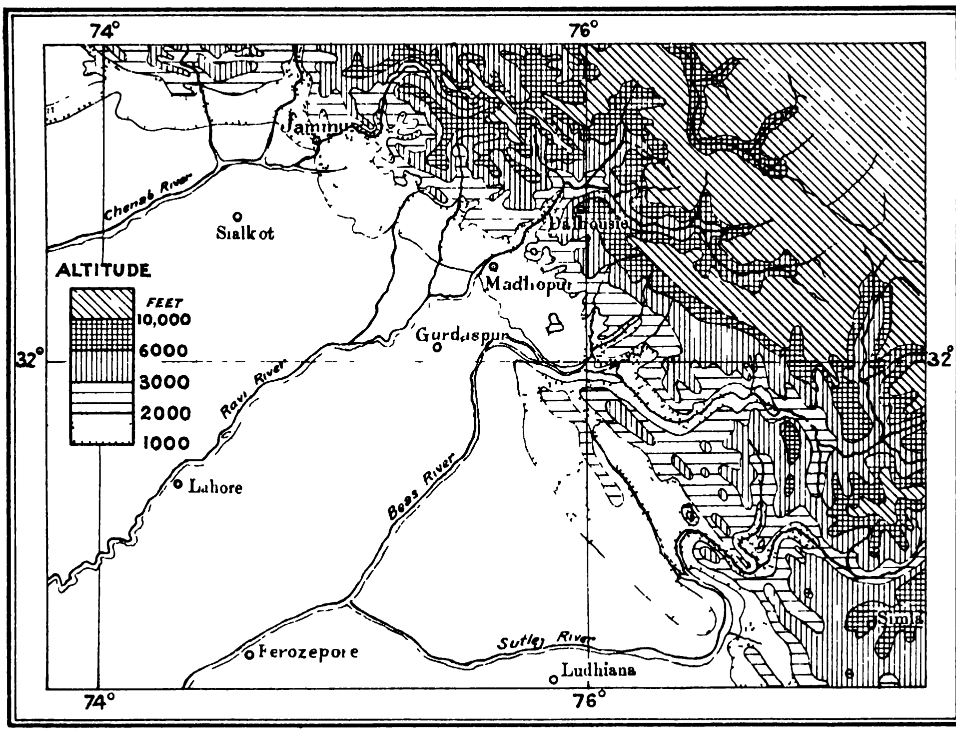

FIG 1 MAP SHOWING THE SITUATION OF LAHORE IN RELATION TO THE EAST PUNJAB HILLS

HOURLY RAINFALL AT LAHORE

BY

V. DORAISWAMY IYER, B.A. AND V. LAKSHMINARASIMHAN, B.A.

(Received on 25th May 1935.)

Abstract.—The hourly rainfall records of the Lahore Observatory for the years 1889 to 1922 have been analysed Tables showing the diurnal variation of rainfall, of occasions of rain and of the average amount of precipitation in each rain-hour in different months and seasons of the year have been given Similar tables showing the distribution of the above elements in association with winds from the eight points of the compass have also been given The percentage probability of rainfall with winds from different directions has been calculated It is seen from these that the maximum of precipitation as well as of occasions of rain occurs in the early morning and that rainfall is largely associated with winds from the northeasterly quadrant A tentative explanation is offered that this is probably due to the flow of cold air at night from the western Himalayas.

Lahore, (Lat 31° 34′ N., Long. 74° 20′ E.), is situated in the plains of the Punjab at a distance of about 80 miles from the foot of the Himalayas and about a mile from the left bank of the river Ravi (*Figure 1, Frontispiece*). The observatory is about 4 miles south of the city.

The self-recording raingauge at the observatory was a tilting bucket raingauge by Beckley which was in use from 1887 to 1925. The collecting funnel was placed on the terraced roof of the observatory, 24 ft above ground and 1½ ft. above terrace, and the recording apparatus was housed in one of the office rooms below. The rain falling into the large funnel (9½ inches across the mouth and 16 inches deep) was conveyed by a lead pipe to the tilting bucket in the recording portion. In this type of instrument, the bucket which receives the rain from the funnel is attached to one end of an arm and counterpoised by a weight at the other end. The arm carrying the bucket and counterpoise is suspended from two pillars and is also connected by a linked parallel movement to the pencil which records the rainfall on the drum of the instrument, which is actuated by clock work. As the rain enters the bucket, it depresses it and draws the pencil across the moving chart to a distance corresponding to the amount of water received. When the bucket contains the right quantity of rain, 0·2″, it automatically tips over and the water flows away through an outlet pipe. After releasing its contents the bucket returns immediately to its initial position, provision has been made for the accumulation of the rain during the second or so in which the bucket is inverted, so that none is spilt or lost.

There was also a Beckley's anemograph at the observatory, mounted on a masonry tower specially erected for the purpose. The height of the cups was 55 ft. above ground and it had been in use since June 1889.

Meteorologically the year at Lahore may be divided into four seasons as follows :—

Winter	December to March.
Summer	April to mid-June.
The monsoon season	Mid-June to September.
Autumn	October and November.

The clear weather which characterises the Autumn in northwest India comes to an end in the middle of December, when the winter rains, so important for the wheat crop of the Punjab, are ushered in by the advent of the disturbances entering India from the west Even in the first fortnight of December the little rain that occasionally falls is associated with early winter disturbances and hence the whole month of December is included in the winter season The winter disturbances have been shown to be continuations of the European depressions in the Mediterranean region , they advance over the highlands of Persia and enter northwest India. Four to five disturbances occur in each of the winter months, but they seem to become less active in the central Punjab plains as the season advances, the normal rainfall at Lahore shows a steady decrease from January to March. Temperature begins to rise by the end of March and summer weather prevails from April to about the third week of June. During this season rainfall is generally associated with local dust-storms and thunderstorms In years of prolonged winter conditions, however, late cold weather storms may cause rain in April , as a rule, however, rainfall in this month is light and is only half of that of January. The monsoon, which sets in early in June on the west coast of the Peninsula and in Bengal, does not, on the average reach the neighbourhood of Lahore till the beginning of July. June is in fact hotter than May at Lahore, the mean daily maximum and the average highest maximum in these months being 105°F and 113°F. respectively in May, and 107 F and 115 F in June. It is however seen that the average time of occurrence of the highest maximum of June falls in the second week of the month and that rainfall in the latter half of June, which is six times the rainfall in the first fortnight, is mostly associated with an incursion of monsoon winds into this region. Hence it appears appropriate to include the first fortnight of this month in the summer season and the second fortnight in the monsoon season

The activity of the monsoon is at its height in July and August, but even in those months the rainfall is not continuous, intervals of rainy weather alternating with longish breaks On the average there are only six rainy days in each of these months. The monsoon begins to decline in activity in the beginning of September and usually comes to an end in the third week of the month. The final cessation of the rains is followed by fine autumn weather which, with slight occasional interruptions, lasts till about the middle of December October gets on the average only a quarter of an inch of rain The rainfall during this month, when it occurs, is associated with the inflow of moist winds into this region, either under the influence of depressions advancing into the interior of the country from the Bay of Bengal and on very rare occasions from the Arabian Sea, or due to an early advance of an active winter disturbance from the west November is the driest month of the year, hardly a tenth of an inch being received on the average during this month.

Tabulation of the Records.

The self-recording raingauge was in use, as already stated, during the period 1887 to 1925. The charts were set to local mean time and the tabulations were consequently in local time. The smallest division on the chart was 0·02″, and, as it was of fairly open scale, the rainfall could be easily read off to the nearest

hundredth of an inch. The charts were not tabulated in the first two years, and after 1922 the tilting bucket was not working properly. Hence the data utilised in the present discussion are for the years 1889 to 1922.

The hourly rainfall read off to the nearest hundredth of an inch is tabulated in the usual form with columns for each hour of the day. The monthly totals of these give the amount of rain which has fallen in each hour of the day. By counting the number of occasions of 0·01″ of rain and over in each column the total number of hours with rain, or "rain-hours" in each hourly interval of the day is also obtained.

The hourly rainfall is then classified according to the wind direct on in the hour, which is tabulated under 16 points of the compass The monthly totals of these columns give for each month the total amount of rain which fell with winds from each of the 16 directions These are then grouped under eight points of the compass. A separate column gives the amount under calms. The number of 'rain-hours' associated with winds from each of the 8 points and with calms is also calculated. The monthly figures are then grouped into the four seasons.

Diurnal Variation of Rainfall.

Table I gives the total rainfall and the total number of 'rain-hours' in each hour of the day for the 12 months, the four seasons and the year as a whole. The seasonal values are plotted in *Figure 2* In the last two columns of *Table I* are given the average rainfall recorded by the self-recording raingauge in the period considered and the average for the same period of the rainfall recorded by an ordinary raingauge erected with its funnel at the standard height of 1 ft. above ground level. December is the only month in which the two records agree. In all other months the catch of the self-recording raingauge is smaller than that of the raingauge at 1 ft. above ground Expressed as a percentage of the latter the catch of the self-recording raingauge is as below. –

Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec.	Year.
87	80	91	83	87	92	93	97	88	92	67	100	92

It will be seen that if we exclude the month of November when the low percentage is evidently due to the very scanty rainfall, the percentages vary between 80 and 100. The mean percentage for the year is in fairly close agreement with the results obtained elsewhere for a raingauge at a height of 20 feet above ground [1].

Table III gives the average amount of rain in a rain-hour for each hour of the day in the four seasons and for the year. These figures were obtained by dividing the rainfall amounts in *Table I* by the corresponding number of rain-hours.

Winter.—During this season the day hours get more rain than the night hours. During the day, the afternoon gets more rain than the forenoon in the months of December and March, the reason is probably to be sought in the greater liability to afternoon thunderstorms. In the month of March the average intensity of precipitation is also greater in the afternoon hours. In December and January the day hours have more occasions of rain than the night hours, but in the other months the distribution of 'rain-hours' shows no large variation. The diurnal variation curve of the season exhibits two maxima and two minima, the maxima at 8 hrs. and 15 hrs., and the minima at 11 hrs. and 21 hrs. The average intensity of rainfall of the season is greater in the period 8 to 14 hrs., than in other parts of the day, and exhibits low values in the early hours, 1 to 4 a.m.

Summer.—The rainfall is small between 8 and 14 hrs., the amount that occurs in this interval being only 12 per cent of the day's total. It increases in the later afternoon hours, and the night hours show a further increase, which is maintained till 8 hrs. in the morning The amount of rain in the 14 hours (6 p.m. to 8 a.m.) is 71 per cent. of the total fall of the day The distribution of the number of 'rain-hours' shows more or less similar characteristics. The average intensity is in general greater in the afternoon and the forepart of the night.

The monsoon season, (mid-June to September). Of the total annual rainfall 77 per cent. occurs in this season. The maximum of the rainfall amount and of the 'rain-hours' occurs at 6 hrs., and the minimum at 22 hrs. In the interval 4 hrs. to 10 hrs. more than a third of the rainfall and 'rain-hours' occurs Both the elements have a secondary minimum at 11 hrs., while the rainfall curve exhibits another secondary minimum at 15 hrs, and the 'rain-hours' curve an hour earlier. Both the curves fall rapidly after 16 hrs till they reach the minimum value at 22 hrs In the individual months, as in the season as a whole, about 60 per cent. of the rainfall and of 'rain-hours' occurs in the day time, the proportion of rainfall being greatest, 69 per cent, in the month of August. The average intensity of rainfall is generally small in the first half of the night. It has higher values during the rest of the day, but exhibits no regular variation

Autumn —This is the period of least rainfall at Lahore, only 2 per cent of the annual total occurring in this season During October 59 per cent. of the day's rainfall occurs in the day hours, and occasions of rain are greater in the forenoon than in other parts of the day About 40 per cent of the small rainfall in November occurs in the interval 20 hrs. to 22 hrs.

Year.—The diurnal variation curve of rainfall for the year as a whole is similar to the curve for the monsoon season, with the mean maximum in the early morning and secondary maxima at 12 hrs and 16 hrs After the last maximum the rainfall rapidly decreases and reaches the minimum value at 22 hrs. The curve of 'rain hours' is in the main similar to the rainfall curve, there are two maxima in the early morning hours with another secondary maximum at 15 hrs, while the minimum occurs at 21 hrs. The average intensity is high in the interval 8 hrs. to 13 hrs. and between 17 hrs. and 22 hrs.

It is interesting to compare the diurnal variation of rainfall at Lahore with that at Calcutta and Quetta, (*Figure 3*). In both these stations the maximum of the diurnal variation curve occurs in the afternoon hours. At Lahore on the other hand, although there are secondary maxima at 16 hrs as well as at noon, the main maximum falls at about the time of sunrise, and more than a third of the total rain of the day falls in the morning hours, 4 a m. to 10 a m It would appear from this that although afternoon instability does contribute to increased precipitation, a more important part is played by other factors in producing precipitation.

In the absence of autographic records at other stations in the Punjab it is not possible to say whether this is peculiar to Lahore or is found at other stations also. An analysis of the times of occurrence of thunderstorms in a few recent years indicates that at stations not far from the hills the frequency of thunderstorms is greater at night than during the day; Rawalpindi resembles Lahore in having a morning maximum frequency of thunderstorms. The contiguity of the hills seems to be the contributing factor in increasing the liability to thunderstorms at night.

In his discussion of the air movement over the western Himalayas based upon anemographic observations recorded at Simla, Eliot[2] states that the most important and unique feature of this movement is the alternating current between the hills and plains, which is a permanent feature independent of the change of seasons. The alternating movement consists of an upward movement during the day hours from 8 a.m. to 5 p.m. giving southerly winds with more or less westing, and a downward movement during the night hours from about 5 p.m. to 8 a.m. giving northerly winds with more or less easting. As the prevailing winds in the east Punjab hills are in general from a northeasterly direction during the greater part of the year, the downward movement at night would tend to strengthen this wind, especially, as pointed out by Blanford,[3] where a river valley debouches on the plains. If in addition the run of a deep river valley like that of the Ravi should coincide with the general direction of the nocturnal movement from the hills, it is but natural to expect that the downward flow would be felt to a greater distance in the plains.

The fact that several occasions of rainfall in the early morning hours at Lahore are associated with a shift of the wind to the northeast suggests that similar reasons might account for the early morning maximum of rainfall at that place. This can be offered only as a tentative hypothesis considering the distance of Lahore from the foot of the hills and the absence of observing stations with autographic instruments between the hills and Lahore

Distribution of rainfall in Octants and Probability of Rain.

The total rainfall and the total number of 'rain-hours' associated with winds from the eight principal points of the compass are given in *Table II* for the twelve months, the four seasons and the year *Table IV* gives the average intensity of rain with winds from the eight points for each of the seasons obtained by dividing the total rainfall given in *Table II* by the corresponding number of 'rain-hours' In addition, in order to estimate the wetness of the winds from each direction, the percentage of the 'rain-hours' to the total number of the corresponding winds was worked out (*vide* Sci Notes Vol. 1, No. 2. para. 10) These figures of the percentage probability of rain based on data from 1889 to 1905 are given in *Table V*.

The wind data necessary for this calculation were taken from Vol. XVIII, Part IV, of the Indian Meteorological Memoirs.

The distribution in octants of rainfall and of 'rain-hours' as well as of the frequency of winds and of the percentage probability of rain in the winter and monsoon seasons are shown as wind roses in *Figure 4.*

Winter.—In this season about 40 per cent. of the rainfall and 'rain-hours' occurs with winds from easterly or southeasterly directions while only about 10 per cent. are associated with westerly or southwesterly winds. The average intensity is greatest with southerly winds and decreases as the wind is deflected to either side, and is low with winds from north or northeast. The percentage probability is a maximum, 7 per cent., with a southeast wind in this season. Considering the individual months the maximum is 10 per cent. in January with the most favourable wind direction, south. The probability figures indicate that the rain bearing winds are mostly drawn from the Arabian Sea.

Summer.—Winds from between northwest and northeast cause more than half the rainfall and 'rain-hours,' while with those from east and southeast are associated nearly another 30 per cent. Most of the rainfall with northwesterly winds however occurs in the first fortnight of June; the June rainfall is also responsible for making the average intensity a maximum with northwesterly winds.

The monsoon season.—Most of the rainfall of this season is brought by the deflected Bay monsoon which advances up the Gangetic plain as an easterly current. Rainfall purely due to the activity of this current is only moderate. But when stimulated by the cyclonic storms from the Bay, which usually pass at some distance to the south or east of the Punjab, heavy falls occur. Heavy downpours occur occasionally when, under the influence of a favourable pressure distribution over northwest India, the Arabian Sea monsoon current blowing across the Sind and Kathiawar coasts is strongly directed towards the hills and the sub-montane plains of the Punjab. These facts are illustrated by the distribution of rainfall exhibited in the tables Taking the season as a whole the number of occasions of rain is a maximum with an east wind, which with winds from the neighbouring directions, southeast and northeast, is responsible for 66 per cent of the total number of 'rain-hours'. The distribution of 'rain-hours' in the individual months is mostly similar to that of the season as a whole.

The amount of rainfall exhibits equally high values with an east and with a north wind, with a slight falling off with winds from the intermediate direction The winds from this quadrant, north to east, give 57 per cent of the total rainfall. The average intensity is a maximum with a north wind and a minimum with an east wind Considering the individual months, the amount of rain is a maximum with an east wind in July, east is the seat of a secondary maximum in August, the main maximum occurring with a north wind both in this month and in September This finds an explanation in the tracks followed by the depressions from the Bay, which, as the season advances, curve northwards towards the Kumaon and the east Punjab hills instead of following a westerly track towards the monsoon low in Sind The maximum probability of rain occurs with a northeast wind, with nearly as high values with winds on either side, southeast, the direction of the most prevalent wind, is the seat of a secondary minimum The distribution of probability of rain in individual months is in the main similar to the seasonal distribution

Autumn.—The maxima of the amount of rain, the number of 'rain-hours' and of the average intensity, all occur with a northeast wind and the minima are associated with a wind from the vertically opposite direction.

Year—Taking the year as a whole the maxima of rainfall and of 'rain-hours' occur with an east wind. Both the rainfall and the number of 'rain-hours' exhibit minima with a west or southwest wind Rainfall with calms is found only in the winter and monsoon season.

The greatest probabilities of rain, on the mean of the year, occur with northeast and east winds, and low probabilities with west and northwest winds. The causes which contribute to larger association of rainfall with northeasterly winds have already been discussed.

The opposition between rainfall probability and the frequency of a wind found at Calcutta is also present to a great extent at Lahore. During winter the least probability is associated with the most frequent wind, NW, while the direction of maximum probability lies to the east of the least prevalent wind. In the mon soon season west is the direction of the least probability, west winds being generally dry winds. The most frequent wind is the seat of a secondary minimum of rainfall probability, while the maximum probability occurs with a northeast wind which is one of the least frequent.

The following information regarding the heaviest fall that has occurred in an hour in the different months of the year in the period under discussion, 1889 to 1922, together with the direction of the wind accompanying the fall and brief notes on the weather prevailing at the time, will be found interesting.

Date of occurrence.	Hour.	Rainfall (inches)	Wind direction	Weather notes.
January 13th, 1901	23–24	0 78	S	Associated with a western disturbance whose central area passed close to Lahore.
February 8th, 1915	19–20	0 54	W	Ditto Ditto.
March 3rd, 1904 ..	9–10	0 70	SE	Associated with a western disturbance causing strong indraught of humid winds from north Arabian Sea across Kathiawar
April 21st, 1909 .	4–5	0 73	NE	Associated with a late western disturbance passing over lower Sind and south Rajputana
May 10th, 1893	23-24	0 86	NW	Associated with a 'low' over northwest India causing strong indraught of humid easterly winds into the Punjab
Jun 28th, 1910	11–12	1 83	NE	Associated with a depression from the Arabian Sea disappearing over upper Sind and causing extension of the Bay monsoon into the Punjab
Jul. 31st, 1900 ..	3–4	2 46	E	Associated with a 'low' over upper Sind and the southwest Punjab Lahore had 4 50" in the 24 hours ending 8 hours 31st
Aug. 30th, 1897	16–17	3 20	N.	Occurred during a thunderstorm associated with disturbed weather over Kashmir causing strong indraught from the north Arabian Sea
Sep. 8th, 1922 ..	8–9	2 60	N.	A depression from the Bay passed into Sind on the 7th, leaving pressure distribution favourable for indraught of Arabian Sea winds into the Punjab Lahore had 5 61" in the 48 hours ending 8 hrs 9th
Oct. 1st, 1915 .. .	6–7	0 68	NE	Occurred during a thunderstorm, there was a good indraught of winds from the Bay of Bengal
Nov. 8th, 1911	21–22	0 24	NNE	Associated with the passage of a western disturbance.
Dec. 12th, 1922 .. .	17-18	0 39	ESE	Ditto Ditto

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[1] H. R. Puri, 'Historical Note on the Catch of Raingauges', Ind Met. Dep. Sci. Notes Vol. III, No. 23.

[2] Indian Meteorological Memoirs, Vol. VI, Part V.

[3] H. F. Blanford, 'Climates and Weather of India', p. 36,

TABLE I.—*Total hourly inches of rain* (Roman) *and*

Hours.	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13
January ..	0·93 *25*	0·75 *20*	0·63 *21*	0·82 *17*	0·83 *24*	1·36 *23*	1·14 *25*	1·33 *29*	1·56 *23*	1·76 *23*	1·89 *20*	1·80 *20*	2·18 *25*
February .	0·86 *18*	0·81 *22*	0·94 *16*	0·75 *16*	0·78 *18*	1·66 *17*	1·39 *20*	1·35 *26*	1·49 *18*	1·07 *16*	0·59 *11*	0·95 *13*	0·77 *11*
March .. .	0·70 *12*	0·74 *15*	0·48 *17*	0·61 *22*	1·33 *23*	0·82 *23*	1·13 *24*	0·74 *24*	1·16 *15*	1·24 *12*	1·28 *13*	1·17 *18*	2·50 *19*
April . .	0·38 *16*	1·53 *21*	0·53 *19*	0·79 *19*	1·44 *19*	0·49 *16*	0·93 *12*	0·17 *5*	0·20 *5*	0·25 *7*	0·12 *8*	0·52 *6*	0·27 *5*
May . .	1·02 *11*	1·05 *8*	0·32 *8*	0·52 *10*	0·53 *10*	0·30 *13*	0·40 *9*	0·50 *6*	0·28 *5*	0·08 *2*	0·08 *3*	0·23 *4*	0·22 *4*
June	0·92 *11*	0·64 *11*	1·89 *13*	2·41 *22*	3·01 *27*	6·19 *25*	4·38 *25*	3·99 *28*	2·84 *20*	2·74 *18*	0·92 *12*	2·99 *7*	1·16 *8*
July	6·41 *35*	8·82 *34*	6·72 *43*	10·81 *50*	11·06 *65*	10·65 *56*	10·99 *52*	6·99 *55*	8·98 *38*	9·24 *38*	7·45 *34*	9·20 *45*	11·92 *51*
August ..	2·76 *17*	4·14 *20*	3·73 *29*	5·16 *28*	6·25 *16*	10·56 *57*	13·83 *50*	11·44 *48*	9·04 *45*	10·79 *41*	8·93 *45*	13·20 *56*	10·32 *49*
September ..	1·81 *17*	2·96 *15*	3·37 *19*	5·64 *20*	4·69 *25*	3·90 *23*	2·76 *28*	5·08 *31*	5·97 *29*	4·93 *18*	3·79 *19*	4·11 *20*	97 *22*
October .	0·61 *3*	0·27 *4*	0·08 *1*	0·28 *1*	0·15 *4*	0·03 *2*	0·75 *5*	0·37 *7*	0·41 *6*	0·25 *5*	0·26 *6*	0·20 *5*	0·06 *2*
November ..	0 *0*	0 *0*	0·07 *2*	0·05 *3*	0·02 *2*	0 *0*	0·05 *1*	0·04 *1*	0·04 *2*	0·05 *1*	0·04 *2*	0·02 *1*	0·11 *2*
December ..	0·63 *15*	0·46 *11*	0·27 *7*	0·37 *8*	0·67 *12*	0·57 *12*	0·70 *12*	0·79 *12*	0·47 *15*	0·38 *10*	0·52 *11*	0·76 *15*	0·68 *15*
Winter	3·12 *70*	2·76 *68*	2·32 *61*	2·55 *63*	3·61 *77*	4·41 *75*	4·36 *81*	4·21 *91*	4·68 *71*	4·45 *61*	4·28 *58*	4·68 *66*	6·13 *70*
Summer ..	2·05 *31*	3·00 *35*	1·24 *32*	2·07 *37*	2·38 *39*	1·82 *36*	3·65 *30*	1·92 *20*	0·96 *15*	0·67 *15*	0·58 *15*	1·06 *12*	1·02 *11*
Monsoon ..	11·25 *76*	16·14 *74*	15·32 *99*	23·26 *112*	24·60 *153*	30·27 *154*	29·64 *146*	26·25 *153*	26·35 *127*	27·36 *109*	20·71 *106*	29·19 *126*	26·84 *131*
Autumn ..	0·61 *3*	0·27 *4*	0·15 *6*	0·33 *7*	0·17 *6*	0·03 *2*	0·80 *6*	0·41 *8*	0·45 *8*	0·30 *6*	0·30 *8*	0·22 *6*	0·17 *4*
Year	17·03 *180*	22·17 *181*	19·03 *198*	28·21 *219*	30·76 *275*	36·53 *267*	38·45 *263*	32·79 *272*	32·44 *221*	32·78 *191*	25·87 *187*	35·15 *210*	34·16 *216*

(A) Average recorded by the self-recording

(B) Average recorded by ordinary raingauge

number of 'rain-hours' (Italics) *in the period 1889 to 1922.*

13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24	Total	A	B.
1 66 *25*	1 11 *26*	1 39 *25*	1 21 *21*	1 35 *22*	1 50 *23*	0 78 *18*	0 73 *18*	0 74 *17*	1 25 *18*	1 74 *17*	30 44 *525*	0 92	*1·06*
1 11 *17*	0 78 *22*	1 14 *18*	1 71 *19*	0 92 *21*	0 80 *19*	1 35 *20*	0 61 *12*	0 71 *17*	0 84 *17*	0·78 *18*	24 16 *425*	0 73	*0 91*
1 35 *20*	2 00 *20*	1 64 *17*	0 90 *15*	1 04 *20*	0 69 *17*	1 19 *17*	0 95 *11*	0 58 *18*	0 90 *17*	0 95 *16*	26 09 *423*	0 79	*0 87*
0 65 *8*	0 25 *8*	0 85 *9*	0 74 *7*	0 63 *6*	1 22 9	90 63 13	0 87 *8*	0 85 *14*	0 86 *13*	0 18 *5*	15 35 *254*	0 45	*0 54*
0 89 *5*	2 63 *8*	0 55 *5*	0 39 *5*	0 34 *7*	0 79 *5*	1 19 *12*	0 57 *9*	0 60 *12*	1 10 *10*	1 54 *9*	16 12 *180*	0 47	*0 54*
0 41 *7*	0 74 *8*	1 32 *8*	1 71 *15*	1 03 *13*	1 25 *7*	0 85 *9*	3 03 *20*	2 30 *18*	1 90 *19*	1 20 *18*	49 82 *369*	1 47	*1·60*
9 77 *47*	6 09 *15*	5 38 *31*	5 34 *28*	2 84 *27*	2 59 *24*	1 61 *14*	1 86 *16*	1 42 *16*	4 69 *14*	4 22 *25*	165 05 *886*	4 85	*5·21*
6 96 *12*	8 66 *51*	14 47 *53*	6 93 *45*	3 38 *34*	3 26 *30*	4 08 *28*	2 33 *17*	1 68 *16*	5 30 *20*	3 68 *18*	170 88 *888*	5 02	*5 16*
2 37 *20*	3 16 *19*	3 35 *18*	2 88 *12*	1 58 *15*	2 04 *18*	1 68 *11*	0 68 *9*	0 58 *7*	0 93 *9*	0 78 *12*	73·01 *436*	2 15	*2·43*
0 51 *4*	0 39 *4*	0 26 *1*	0·44 *6*	0·52 *3*	0·24 *6*	0·25 *4*	0·26 *4*	0 65 *8*	0 24 *6*	0·03 *1*	7 51 *107*	0 22	*0 24*
0 08 *1*	0 02 *1*	0 08 *2*	0 04 *1*	0 06 *1*	0 *0*	0 03 *2*	0 33 *3*	0·27 *3*	0 03 *2*	0 03 *2*	1 46 *35*	0·04	*0·06*
0 94 *15*	0 61 *11*	0 72 *18*	0 83 *18*	0 95 *14*	1 01 *15*	0 43 *14*	0 27 *10*	0·37 *13*	0 68 *13*	0 39 *10*	14 47 *309*	0 43	*0·43*
5 06 *77*	4 50 *82*	4 89 *78*	4 65 *73*	4 26 *77*	4 00 *74*	3 75 *69*	2 56 *51*	2 40 *65*	3 67 *65*	3 86 *61*			
1 61 *14*	3 07 *19*	2 17 *18*	1 90 *20*	1 71 *22*	3 10 *19*	2 50 *31*	3 58 *28*	2 81 *36*	3 57 *34*	2 46 *20*			
19 44 *115*	18 46 *123*	23 75 *106*	16 09 *92*	8 09 *80*	8 05 *71*	7 54 *56*	5 76 *51*	4 62 *47*	11 21 *51*	9 14 *67*			
0 59 *5*	0 41 *5*	0 34 *6*	0 48 *7*	0 58 *4*	0 24 *6*	0 28 *6*	0 59 *7*	0 92 *11*	0 27 *8*	0 06 *3*			
26 70 *211*	26 44 *229*	31 15 *208*	23 12 *192*	14 64 *183*	15 39 *173*	14 07 *162*	12 49 *137*	10 75 *159*	18 72 *158*	15 52 *151*			

raingauge (*vide* page 225)

at standard height of 1 foot (*vide* page 225).

TABLE II.—*Total inches of rain* (Roman) *and of 'rain-hours'* (Italics) *under eight directions and calms in the period 1889 to 1922.*

—	N	NE.	E	SE	S	SW.	W.	NW.	Calm.
January	2 58 *55*	4 03 *92*	5 93 *115*	7 52 *111*	4 74 *51*	1 23 *19*	1 17 *21*	1 71 *37*	0 19 *6*
February	2 61 *55*	2 17 *50*	5 52 *81*	4 09 *76*	2 71 *41*	1 25 *22*	2 15 *30*	2 71 *50*	0 57 *12*
March	3 46 *83*	2 20 *60*	5 14 *87*	5 60 *65*	3 45 *13*	2 13 *26*	1 68 *20*	2 31 *42*	0 12 *8*
April	3 84 *52*	3 45 *57*	2 54 *17*	1 43 *27*	0 66 *16*	0 76 *12*	1 69 *20*	0 98 *24*	0 *0*
May	4 54 *36*	2 86 *38*	1 71 *25*	1 11 *18*	0 75 *13*	0 42 *8*	1 83 *15*	1 79 *20*	0 *0*
June	9 51 *19*	11 02 *72*	6 18 *72*	6 51 *54*	1 58 *19*	1 44 *19*	1 35 *21*	10 13 *48*	0 *0*
July	26 49 *106*	31 10 *113*	35 74 *209*	30 05 *211*	14 62 *86*	6 76 *33*	4 85 *28*	8 96 *37*	0 76 *6*
August	31 95 *116*	27 33 *114*	30 56 *226*	25 95 *167*	24 94 *101*	9 59 *45*	7 35 *30*	10 54 *54*	0 06 *4*
September	16 39 *78*	13 19 *80*	11 79 *96*	13 34 *78*	6 75 *43*	3 41 *13*	3 14 *20*	4 89 *23*	0 11 *5*
October	1 47 *20*	2 28 *25*	1 09 *23*	0 93 *13*	0 48 *6*	0 15 *4*	0 29 *7*	0 82 *9*	0 *0*
November	0 42 *7*	0 36 *6*	0 14 *5*	0 15 *7*	0 01 *1*	0 05 *1*	0 05 *2*	0 28 *6*	0 *0*
December	2 85 *70*	2 81 *68*	2·40 *44*	3 82 *55*	0 52 *13*	0 23 *9*	0 48 *6*	0 96 *31*	0 40 *11*
Winter	11 50 *263*	11 21 *270*	18 99 *327*	21 03 *307*	11 42 *148*	4 84 *76*	5 48 *77*	7 69 *160*	1·28 *37*
Summer	10 85 *105*	9 34 *122*	6 88 *99*	5 60 *66*	2 43 *40*	1 92 *30*	4 07 *40*	7·81 *64*	0 *0*
Monsoon	81 87 *332*	79 61 *412*	81 64 *576*	72 79 *489*	46 87 *238*	20 46 *100*	16 14 *94*	29 48 *142*	0·93 *15*
Autumn	1 89 *27*	2 64 *31*	1 23 *28*	1 08 *20*	0 49 *7*	0 20 *5*	0 34 *9*	1 10 *15*	0 *0*
Year	106 11 *727*	102 80 *835*	108 74 *1030*	100 50 *882*	61·21 *433*	27·42 *211*	26·03 *220*	46·08 *381*	2·21 *52*

Table III.—*Average amount of rain in a 'rain-hour' during each hour in the four seasons and the year.*

—	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	23–24
Winter ..	·04	·04	·04	04	·05	06	05	05	07	07	07	07	09	07	05	06	·06	06	05	05	05	·04	·06	·06
Summer	·07	09	04	06	06	05	12	10	06	04	04	09	09	11	16	12	·09	08	16	08	13	·08	·11	·12
Monsoon	·15	22	16	21	16	20	20	17	21	25	20	23	20	17	15	22	18	10	·11	·13	11	10	·20	·14
Autumn	·20	07	03	05	03	01	13	05	06	05	04	04	04	12	08	06	07	15	·04	05	08	·08	·03	·02
Year .	09	12	10	13	11	14	14	12	16	17	14	17	16	12	12	15	12	08	09	09	·09	·07	·12	·10

Table IV—*Average amount of rain in a 'rain-hour' under eight directions and calms in the four seasons and the year.*

—	N	NE	E	SE	S	SW	W	NW	Calm
Winter	04	04	06	07	08	06	07	05	03
Summer	10	08	07	08	06	06	·10	·12	.
Monsoon	25	19	·14	·15	·20	20	·17	21	·06
Autumn	·07	·09	·04	05	07	04	04	07	.
Year	15	12	11	11	14	13	12	·12	04

TABLE V.—*Percentage frequency of winds* (Roman) *and percentage probability of rain* (Italics) *under eight directions and calms.*

—	N.	NE	E	SE	S	SW	W.	NW.	Calm.
January .	26 2 *1 3*	5 3 *8 1*	6 4 *7 8*	6 8 *7 9*	2 7 *9 9*	2 3 *3 3*	8 9 *1 0*	32 3 *0 7*	9 0 *0·5*
February ..	24 4 *1 3*	8 2 *2 4*	7 6 *4 7*	5 8 *6 3*	3 0 *4 9*	2 8 *4 9*	10 0 *0 8*	31 6 *0 7*	6·6 *1·5*
March .	25 0 *1 6*	10 8 *2 6*	8 2 *1 3*	5 8 *4 1*	3 8 *3 6*	4 8 *1 6*	9 3 *0 8*	28 1 *0 8*	4·2 *0·4*
April . ..	27 3 *0 6*	12 0 *1 4*	8 0 *1 1*	6 1 *1 0*	4 4 *0 4*	4 2 *0 8*	8 4 *0 2*	25 5 *0 1*	4 0 *0·0*
May .	22 7 *0 8*	12 2 *1 4*	12 0 *0 4*	12 0 *0 6*	6 0 *0 6*	6 0 *0 6*	9 0 *0 8*	16 8 *0 6*	3 3 *0·0*
June ..	10 8 *2 0*	7 7 *4 3*	13 5 *2 5*	20 9 *1 4*	8 5 *0 9*	11 7 *0 5*	11 9 *0 7*	11 5 *1 9*	3·7 *0·0*
July ..	8 1 *6 3*	8 0 *6 6*	17 7 *5 4*	29 3 *3 2*	10 5 *3 3*	10 4 *1 7*	6 8 *1 4*	5 5 *2 2*	3 7 *1 2*
August	7 9 *5 4*	7 7 *5 0*	18 1 *3 1*	25 2 *2 2*	10 9 *3 7*	9 5 *1 6*	8 9 *1 7*	6 7 *2 0*	5 1 *0 2*
September	11 9 *1 8*	10 0 *2 3*	13 2 *2 2*	16 9 *1 8*	7 5 *1 8*	9 4 *0 4*	13 9 *0 3*	11 5 *0 3*	5 7 *0 0*
October	21 0 *0 2*	8 8 *0 7*	10 5 *0 6*	11 3 *0 5*	5 9 *0 1*	4 9 *0 0*	8 8 *0 1*	19 8 *0 1*	9 0 *0 0*
November	26 3 *0 2*	5 1 *0 7*	5 9 *0 1*	5 0 *0 2*	1 6 *0 6*	1 9 *0 5*	8 6 *0 0*	32 8 *0 1*	12 8 *0 0*
December	24 5 *1 2*	5 7 *5 3*	6 4 *2 4*	4 2 *5 4*	1 6 *2 6*	1 9 *1 3*	8 4 *0 3*	35 6 *0 3*	11 7 *0 7*
Winter ..	25 0 *1 4*	7 5 *4 1*	7 1 *4 8*	5 6 *6 9*	2 8 *5 3*	3 0 *2 6*	9 1 *0 7*	31 9 *0 6*	7 9 *0 7*
Summer	22 2 *0 7*	11 3 *1 5*	10 7 *0 8*	11 3 *0 8*	5 8 *0 6*	6 4 *0 7*	9 3 *0 4*	19 2 *0 5*	3 7 *0 0*
Monsoon	9 5 *3 9*	8 5 *4 6*	15 9 *3 8*	23 3 *2 4*	9 5 *2 8*	10 0 *1 1*	10 2 *0 8*	8 4 *1 0*	4 7 *0 3*
Autumn	23 6 *0 2*	7 0 *0 7*	8 2 *0 5*	8 2 *0 4*	3 8 *0 2*	3 4 *0 1*	8 7 *0 0*	26 2 *0 1*	11 0 *0 0*
Year	19 7 *1 3*	8 5 *3 1*	10 6 *2 9*	12 3 *2 4*	5 5 *2 4*	5 8 *1 2*	9 4 *0 6*	21 6 *0 6*	6 6 *0 3*

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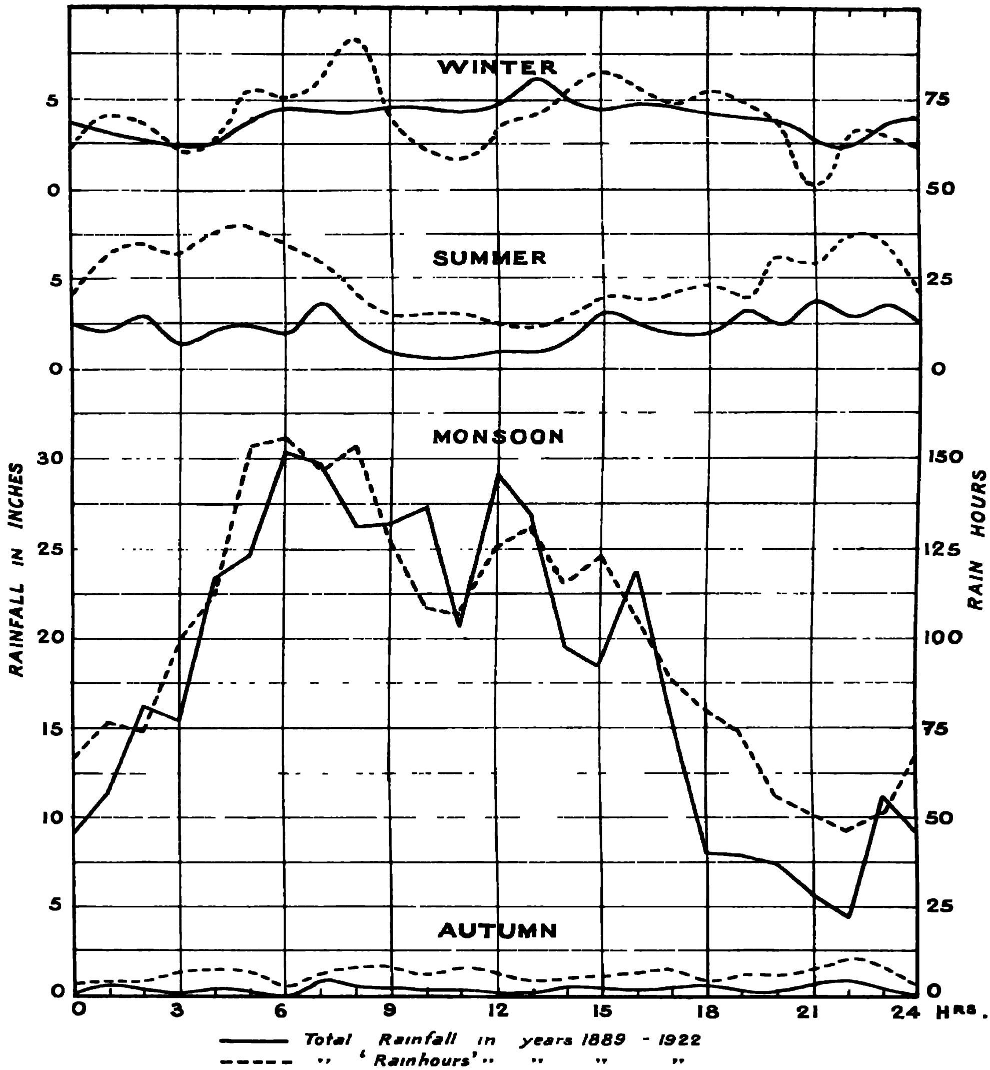

FIG 2 DIURNAL VARIATION OF RAINFALL AT LAHORE

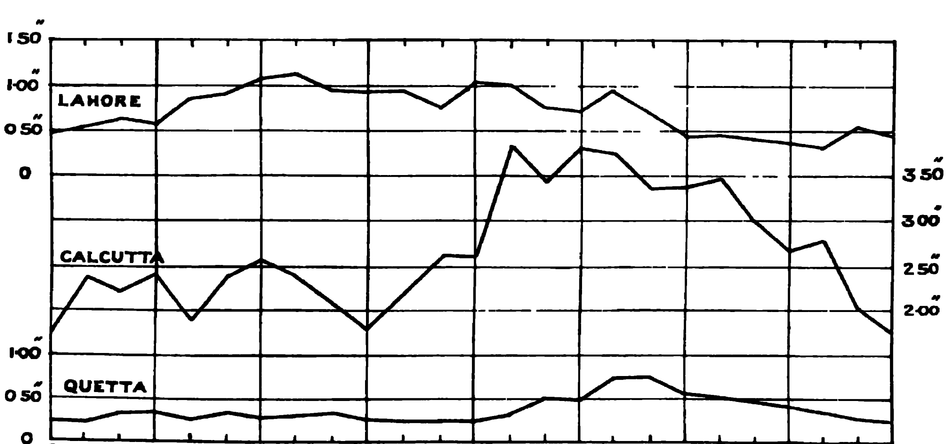

FIG 3 DIURNAL VARIATION OF RAIN DURING THE YEAR AT LAHORE CALCUTTA AND QUETTA

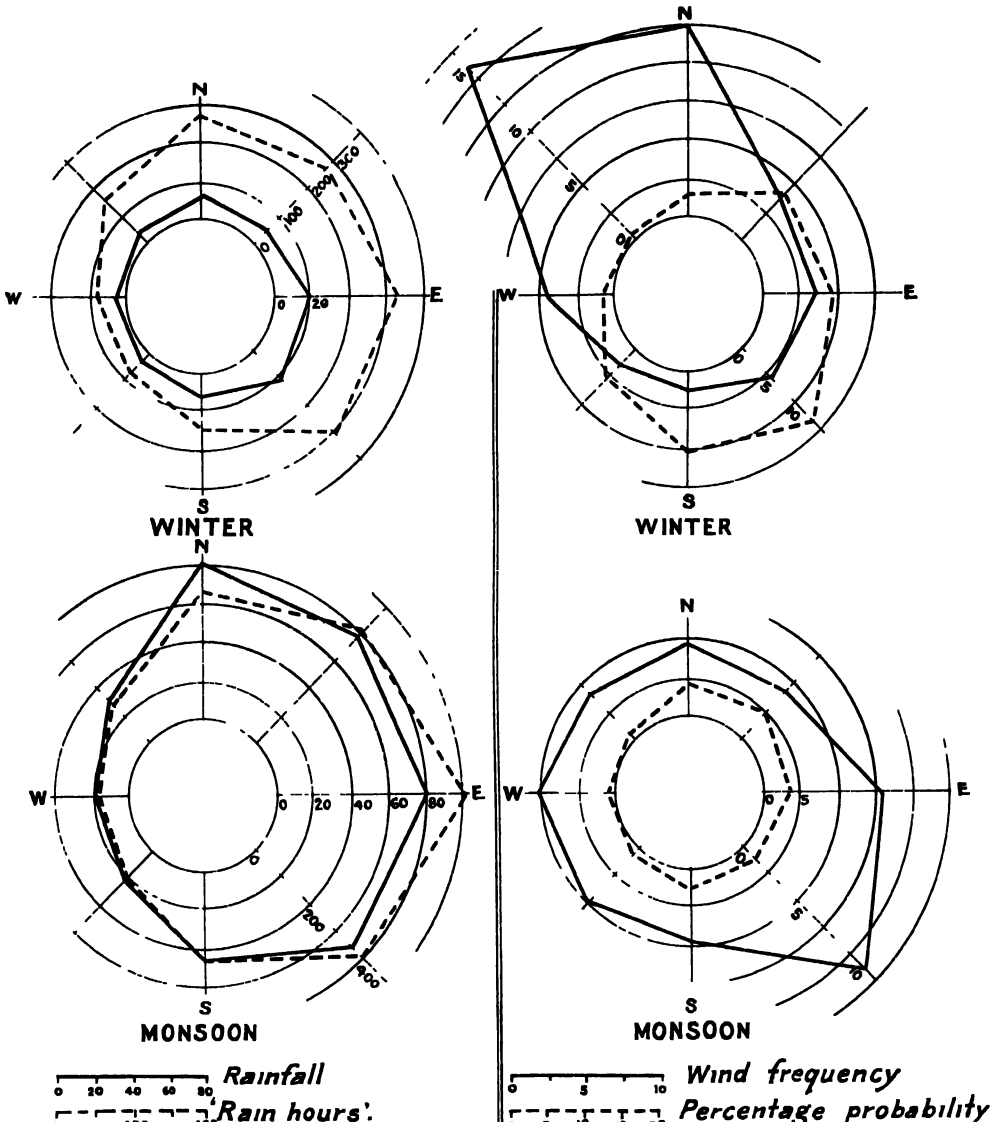

FIG 4 DISTRIBUTION IN OCTANTS OF RAIN AND WIND AT LAHORE

NO—SN6/67

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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Measurement of Vertical Currents in the Atmosphere, mainly of Thermal Origin, with Pilot Balloons.

BY

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MEASUREMENT OF VERTICAL CURRENTS IN THE ATMOSPHERE, MAINLY OF THERMAL ORIGIN, WITH PILOT BALLOONS.

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Summary.—The paper discusses the results of some measurements of vertical currents in the atmosphere obtained with liftless balloons at Poona. These balloons were first carried up to different heights in the atmosphere varying from about 0.5 km. to 2.0 km. and released there by means of timed fuses. On clear days in the dry season vertical currents are generally weak in the mornings and marked in the afternoons; on one occasion the upward velocity went up to 14 km./hr. The vertical currents observed on some days with cumulus and cumulo-nimbus clouds are also described.

In the particular ascents discussed in the present note, the vertical currents were mainly thermal in origin and not due to flow of air over obstacles.

Introduction.—It is well-known that vertical currents of considerable intensity and extent are of fairly frequent occurrence in the atmosphere. Measurements of such currents are however few, the main reason for their scarcity being that the vertical velocities are generally small compared to the horizontal velocities of air movement. In Europe, manned balloons and pilot balloons have been used for their investigations[1—4]. In the Forschungs-Institut of the Rohn-Rossitten Gesellschaft[5] which devotes special attention to the scientific study of motorless flying, sail-planes (gliders) have been utilised for studying the vertical currents developed under a wide variety of conditions, such as those associated with wind movement over hilly country, convection over insolated ground, growth of cumulus and cumulo-nimbus clouds and movement of line-squalls. In Britain, the up and down movements caused by eddies in gusty weather have been inferred from the fluctuating readings of accelerometers carried in aeroplanes.[6] The systematic use of tailed balloons for the measurement of upper winds in India has provided many examples of marked vertical currents but few of them have been published, the only exception being the results obtained at Agra on a day of slightly disturbed weather.[7] In the present note are discussed some experiments carried out at Poona on the measurement of vertical currents in the atmosphere by the use of liftless balloons.

Method used.—The pilot balloons used for investigating the vertical currents were provided with tails of 25 metres length with paper flags attached to them at 6¼, 12½ and 25 metres and small bags of sand near the lowest flag. The weight of the sand and the amount of hydrogen in the balloon were so adjusted that the combined system of balloon, tail, flags and sand had no resultant free lift. This system was carried up to the required height by means of another balloon and released there by means of a timed fuse. The sand-bag practically eliminated the slant of the tail, and the flags, in addition to serving as end-marks for the moving base-line, also

helped to damp out any tendency to pendular motion of the tail. Except when the altitude of the balloon was more than 65° the angle subtended by the balloon and flags as read in the scale of the eye-piece of the theodolite could be used to determine with fair accuracy the height of the balloon. Readings of azimuth, altitude and tail-length were taken every half-minute The balloons used were of rubber and either of 90″ or 70″ size, the weight of the sand-bag being usually 50 gms The no-lift condition was adjusted to within 2 or 3 gms the small net lift being generally positive. With the particular weight of balloons, load and free lift, a residual free lift of 2 gms. would mean a rate of ascent of about 1·5 km./hr.*

Results.—The balloons were released at different times of the day varying from 8 hrs to 18 hrs Notes on some of the successful ascents made on different days are given below In the tables which follow, the following symbols have been used.

H_0 —Height above ground in kilometres at which iftless balloon was detached

H_x, H_n —Maximum and minimum heights reached by liftless balloon.

t—Duration of flight of liftless balloon in minutes.

24TH DECEMBER 1930.—Clear, anticyclonic weather prevailed over Poona on this day and four successful ascents were made.

TABLE I.

Ascents on 24th December 1930

Time hrs I S T.	H_0 (km)	H_x (km.)	H_n (km)	t (min)
1103	0 5	0 7	0 5	10
1234	1 1	1 3	1·1	34
1411	1·25	1·3	0 8	19
1618	1·4	1·8	0 5	49

The height-time curves of the balloons are shown in *Fig. 1* The

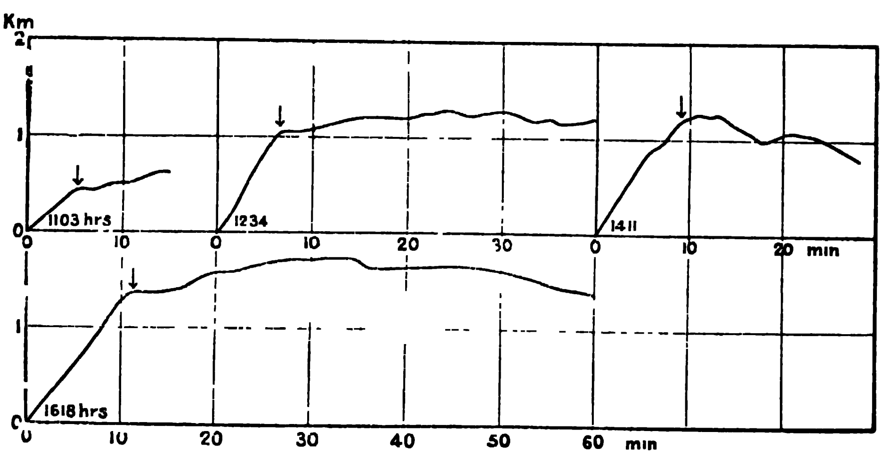

Fig. 1. Height-time curves of some Pilot Balloons sent up on 24th December 1930

*As there would be a small, slow leakage of gas from the balloon and as the amount of the leakage would vary from balloon to balloon, it was not considered worth while to make a correction on this account.

time at which the liftless balloon was detached is indicated by an arrow. The first ascent shows an abnormally low rate of ascent for the combined system of balloons being only 6 km./hr. against the normal 7·5 km./hr. The second and third ascents show an excess rate of ascent of about 2 km./hr. The ascent at 1411 hrs. shows a downward current of 5 km./hr. lasting for about 5 minutes followed by an upward current. The last ascent shows an upward current lasting for 2-3 minutes. It is probable that the gradual descent of the last balloon which commenced about 50 min. after release was due to leakage of gas. On the whole, the vertical currents were feeble on this day.

20TH JANUARY 1931.—There were eight ascents on this day, details about which are given in *Table 2* below :—

TABLE 2.

Ascents on 20th January 1931

Time (hrs.)	H_0 (km.)	H_x (km.)	H_n (km.)	t (min.)
0839	0 4	0 4	0 3	7
0921 .. .	0 9	0 9	0 8	19
1006	0·8	0 8	0·6	11
1049	2·0	2·1	1·9	44
1216	3·1	3 2	3·1	6
1307	1·9	2·2	0 2	64
1445	0·6	1·7	0 1	100
1652	Liftless balloon not released.			

On this day also, the weather was clear over Poona, although a western disturbance was active in the North-West Frontier Provinces and the Punjab. The trajectories of the balloons sent up between 0839 and 1216 hrs. showed that at those times there was a southeasterly wind up to about 1·3 km. above ground and a westerly wind above. In the afternoon, there were large and irregular changes of horizontal movement probably connected with the mixing of the lower and upper layers of air

In *Fig. 2* are shown the height-time curves of all the balloons sent up on this day and the trajectories of those sent up at 1216 and 1445 hrs. The height-lines of the morning

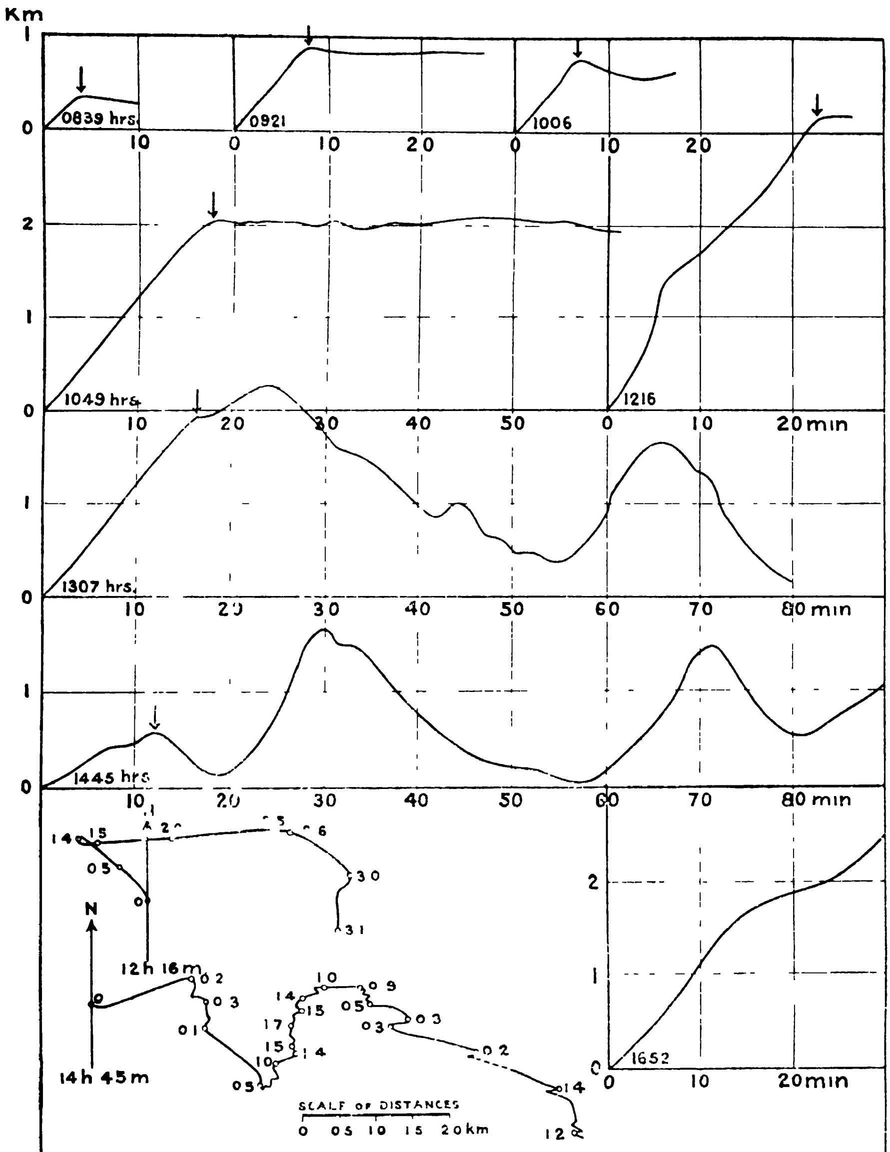

Fig 2. Height-time curves and trajectories of some Pilot Balloons sent up on 20th January 1931.

flights do not show strong vertical currents, but the flight at 1216 hrs. shows abnormally high rate of ascent before the release of the liftless balloon. The two balloons sent up at 1307 and 1445 hrs. show vigorous up and down currents lasting for comparatively long periods of time.

In the second of the above two flights, the mean rate of ascent of the combined system before the release of the liftless balloon was only 3 km./hr. against 7·5 km./hr. which would normally be expected. Upward and downward velocities going up to 14 km./hr. and 9 km./hr. respectively were shown by the latter course of

the liftless balloon. In the flight commencing at 1652 hrs. although the liftless balloon was not released, there are unmistakeable signs of vertical currents.

11TH FEBRUARY 1931.—There was a very weak low pressure area over the east Central Provinces connected with a western disturbance. The weather over Poona was clear. The times and other details of the ascents are tabulated below.

TABLE 3.

Ascents on 11th February 1931.

Time (hrs.)	H_0 (km.)	H_x (km.)	H_n (km.)	t (min.)
0827	0·9	1·4	0·9	21
0921	1·2	1·5	1·2	11
1003	Liftless balloon not released.			
1033	1·7	2·3	1·7	12
1123 .. .	Liftless balloon not released.			
1301	1·8	2·0	1·8	8
1350	0·8	1·2	0·8	21

The height-time curves and trajectories of all the ascents on this day are given in *Fig. 3.* The trajectories show an interesting change of upper wind during the day. In the morning, there was an easterly current about 0·9 km. deep near the

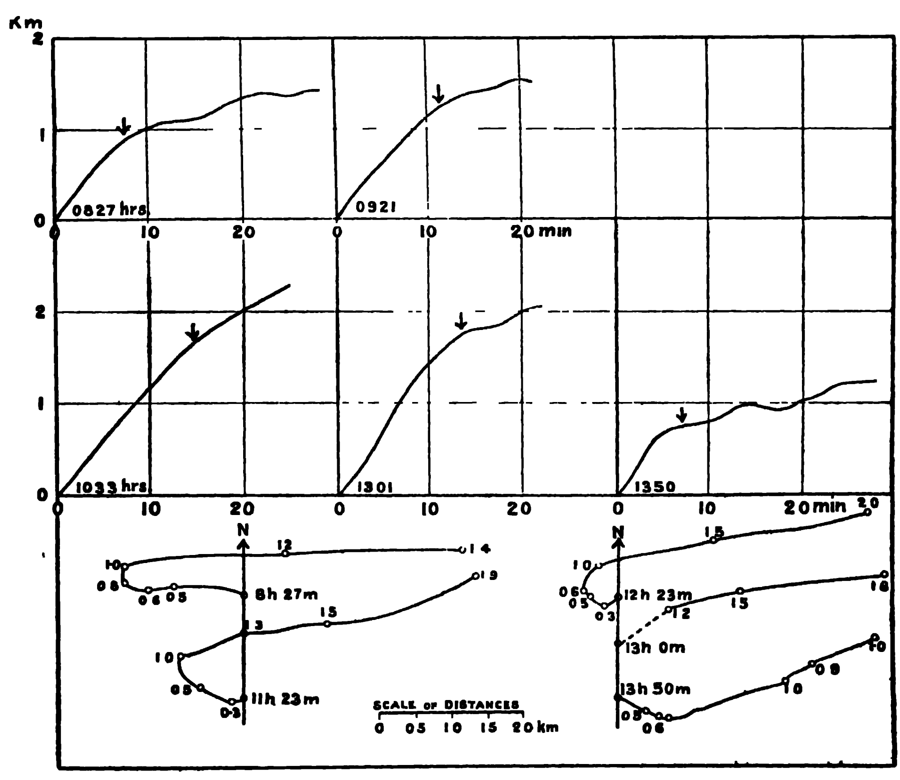

Fig. 3. Height-time curves and trajectories of some Pilot Balloons sent up on 11th February 1931.

M29DGOb

surface with a westerly current above. The former became shallower with the progress of the day and disappeared by 1300 hrs. The height lines of the ascents, which are given in the same figure show that although there were vertical currents, they were rather feeble. The strongest currents were shown by the balloons sent up at 1350 hrs., the vertical velocities going up to only 3 km./hr.

The ascents on this day show that from the mere fact that there exist two superposed streams from different directions, one cannot infer that the vertical currents that may be developed will be intense. The lapse-rates of temperatures in the two layers and the change of temperature taking place at the transition will naturally determine the stability as regards vertical displacements. Unfortunately, no temperature data are avilable to compare conditions on this day with those on 20th, January 1931.

29TH MARCH 1933.—There were only two successful ascents on this day, one at 0817 hrs. and the other at 1243 hrs. The liftless balloon was released at 1·0 km. in the first ascent and at 0 6 km. in the second. The first showed only an ascending current with an average strength of 3 km /hr and the second both ascending and descending currents of about the same average strength.

8TH APRIL 1933.—This was also a clear day, but it was cooler than normal in the central parts of the country, Gujarat and the eastern parts of Bombay Deccan. Information about the ascents is contained in *Table 4.*

TABLE 4.

Ascents on 8th April 1933

Time (hrs)	H_0 (km)	H_x (km)	H_n (km)	t (min.)
1004	1·2	1 7	1·2	9
1049	1·7	3 0	1·7	20
1242	1·3	2·6	1·3	19
1330	0·4	0·7	0·4	16
1419	1·8	2·4	1·8	20
1507	0·6	0·9	0·3	30
1559	0·8	1·1	0·7	29

The height-time curves of the balloons are shown in *Fig. 4* Perhaps owing to

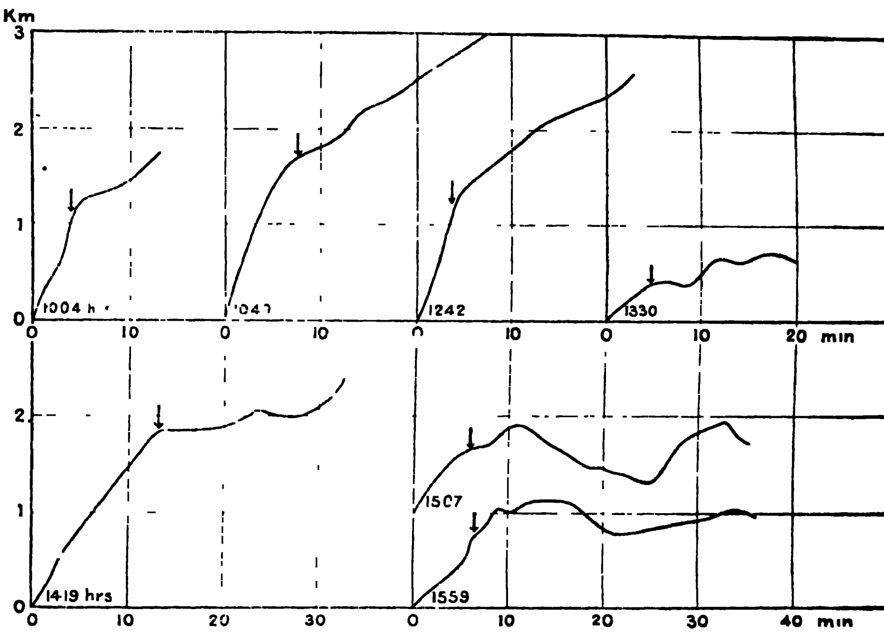

Fig. 4. Height-time curves of some Pilot Balloons sent up on 8th April 1933.

the extra instability due to the coolness of the upper air, the rates of ascent were exceptionally high in the first three ascents before the release of the liftless balloons and there were also strong upward movements of the liftless balloons One is tempted to suspect that there was some error in free lift, but the original records do not show any special reason for suspicion Assuming that there was no error in the measurement, the intensity of the ascending currents were from 4 to 10 km/hr. The afternoon ascents show both ascending and descending currents For example, the flight commencing at 1507 hrs shows descending currents of 2-6 km/hr and ascending currents going up to 6 km./hr.

10TH APRIL 1933.—There were only two ascents on this day; both were made in the afternoon at a time when there was growing cumulus The first ascent commenced at 1533 hrs. and the second at 1637 hrs Thunder was heard between 1615 and 1725 hrs It is interesting to note that in the second ascent, there was sustained upward current from the ground up to 3 3 km, the average upward velocity being about 4 km./hr. and the maximum velocity about 7 km/hr.

9TH OCTOBER 1934.- There was an extensive, diffuse low pressure area lying over the whole of the Bay of Bengal and part of the Deccan. On the afternoon of this day, there were thunderstorms at Poona and its neighbourhood, rain fell at Poona between 1552 and 1600 hrs. Twelve special ascents were made on this day, particulars of eight of which are given in *Table 5.*

TABLE 5.

Ascents on 9th October 1934

Time (hrs.)	H_o (km)	H_x (km)	H_n (km.)	t (min)
0930	1 1	1 1	0 2	9
0941 ..	2·6	3 2	2 6	16
1015 .	1 1	2 0	1 1	23
1105 .	1 3	1·3	1 2	4
1245	2 3	2 8	2 2	11
1325 ..	0·7	1·7	0 7	25
1408 ..	1·6	1 7	1·6	0
1516 ..	0 5	1 7	0·5	33

The height-time curves of all the ascents and the trajectories of three of them are shown in *Fig. 5.* The ascent at 1245 hrs. showed a large upward current of nearly

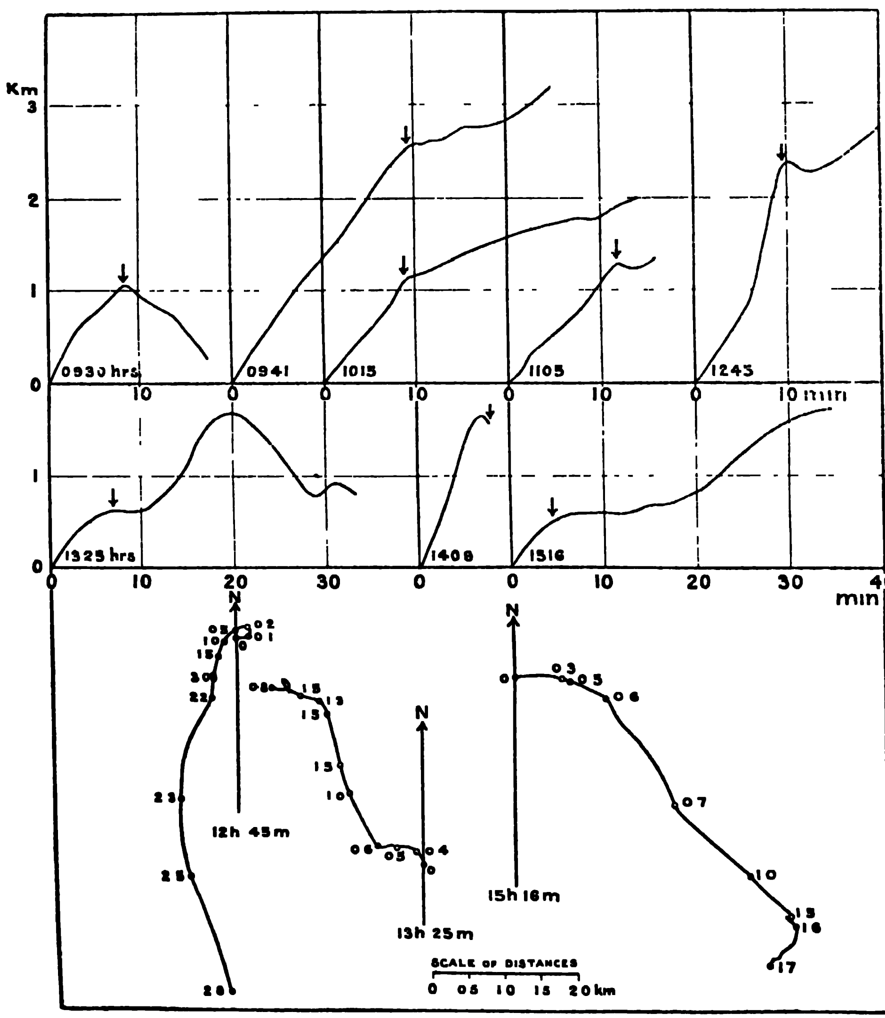

Fig. 5. Height-time curves and trajectories of some Pilot Balloons sent up on 9th October 1934.

16 km./hr.* before the release of the liftless balloon Both upward and down ward currents were shown by other ascents also, the one sent up at 1325 hrs. indicating up and down currents of about 8 km./hr It is interesting to note that there were considerable differences between the trajectories of the balloons sent up at 1245, 1325 hrs and 1516 hrs. the first one showing a northerly, the second a southerly and the third a northwesterly wind between 0 5 and 1 5 km The autographic charts of wind and temperature, which are reproduced in *Fig 6* (*Plate I*), show weak winds with fluctuating direction till 1525 hrs and moderately strong westerly to west-northwesterly wind later. The fall of dry bulb and rise of wet bulb temperature a little before the onset of the westerly wind is noteworthy It suggests that the westerly wind was of the nature of a sea-breeze[8] Rain commenced about half an hour after the beginning of the westerly wind

12TH OCTOBER 1934 —On this day, the low pressure area in the Bay was concentrating into a depression Thundershowers occurred extensively in the Deccan There were cumulus and cumulonimbus clouds at Poona and four special ascents were made, all in the afternoon, particulars of which are given in *Table 6.*

TABLE 6

Ascents on 12th October 1934

Time (hrs)	H_o (km)	H_x (km)	H_n (km)	t (min)
1318	1 6	2 0	1 6	8
1343 .. .	1 4	2 0	1 4	10
1421	0 6	1 7	0 6	16
1540	0·8	1 2	0·8	4

The height-lines and trajectories of these are reproduced in *Fig. 7.* There

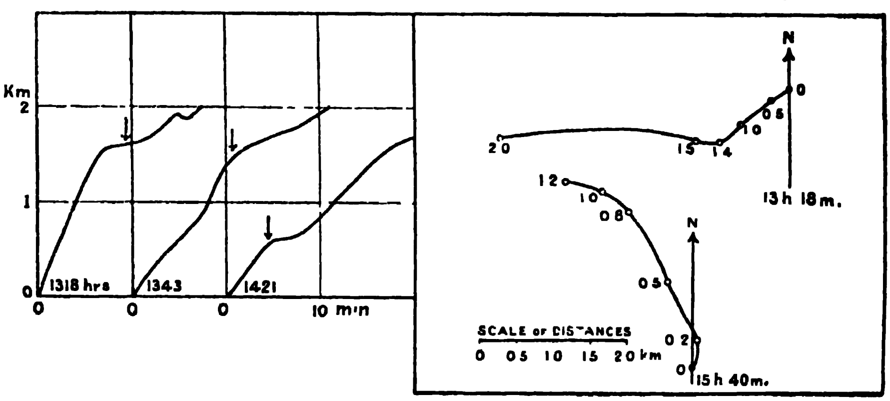

Fig. 7. Height time curves and trajectories of some Pilot Balloons up on 12th October 1934.

was a shower between 1445 and 1455 hrs and another between 1550 and 1620 hrs Vertical currents going up to 7 km./hr. are noticeable in all the height-lines. The trajectories show that a northeasterly current at 1421 hrs.† was replaced by a southeasterly at 1540 hrs. The autographic charts from Poona are reproduced in *Fig. 8* (*Plate II*).

*To obtain this, the normal rate of ascent calculated from the net free lift and weight was assumed.

†Trajectory not reproduced

Discussion.- The trajectories of the ascents of the no-lift balloons were examined with reference to the contour of the surrounding country to see if the vertical currents could be associated with topographical features No definite connection could be established and it may therefore be taken that the currents revealed by these particular ascents were mainly due to thermal turbulence. It should be remembered that the releases of the no-lift balloons generally took place at heights varying from 0 5 to 2 km. above ground, while the variations of ground-level in the region of travel of the balloons were not more than 0 2 km.

The strength of the up and down currents recorded above may be compared with some of those observed in Europe German workers, using liftless pilot balloons released from aeroplanes have observed vertical currents going up to 10 km/hr. (2 8 mps) on a hot afternoon An upward wind of nearly 12 km/hr (3 2 mps.) was experienced at a boenfront by Kronfeld flying in his sail-plane 'Wien' between the heights of 950 and 1600 metres Still stronger were the currents encountered by Bedau in a towering cumulus in which the vertical velocity went up to more than 21 km hr (6 mps) The readings obtained in England with accelerometers carried in aeroplanes flying in gusty weather showed vertical currents whose most frequent velocities lay between 2 and 5 km/hr but occasionally went up to 18 km/hr (17 ft/sec) in cumulus clouds

Recently, regular flights of pilot balloons with extra ballast to reduce the slant of the tail have been made at Poona and these show that measurable vertical currents are noticeable in the first two kilometers on more than 50% of the sunny days between 10 hrs. in the morning and sunset Even on clear days, their magnitude may be as much as on cumulus days The maximum upward velocity that has been observed with pilot balloons is 15 km/hr in heavy cumulus weather There have however, been other occasions, especially during thunderstorms, when sounding balloons having a normal rate of ascent of about 16 km/hr. have been carried down from heights of about 10 km. to 2 or 3 km and again been carried up These facts show that the intensity of the vertical currents experienced in India are about the same as those met with in Europe, but it is probable that they often extend to greater heights

Gliders of modern design have rates of descent as low as 2 to 3 km/hr and it is clear that on most sunny days in the Deccan (and presumably in other parts of the country as well) the thermal currents that are developed after 10 o'clock would be capable of sustaining soaring flight of gliders for a few hours at a time.

All the members of the staff of the Upper Air Section have taken part in this work in some way or other, and our best thanks are due to them for their hearty co-operation.

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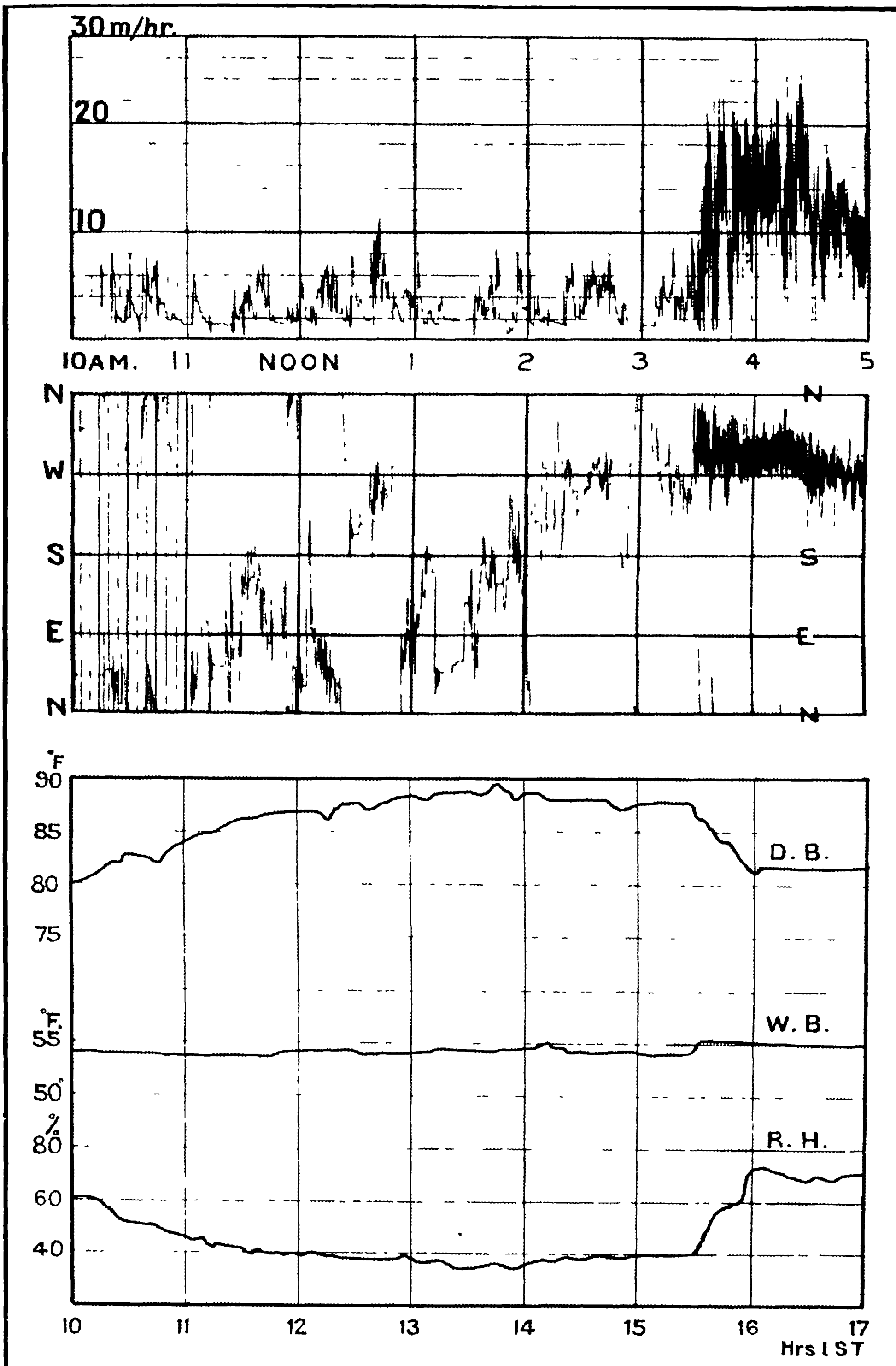

FIG. 6 WEATHER AT POONA ON 9-10-1934

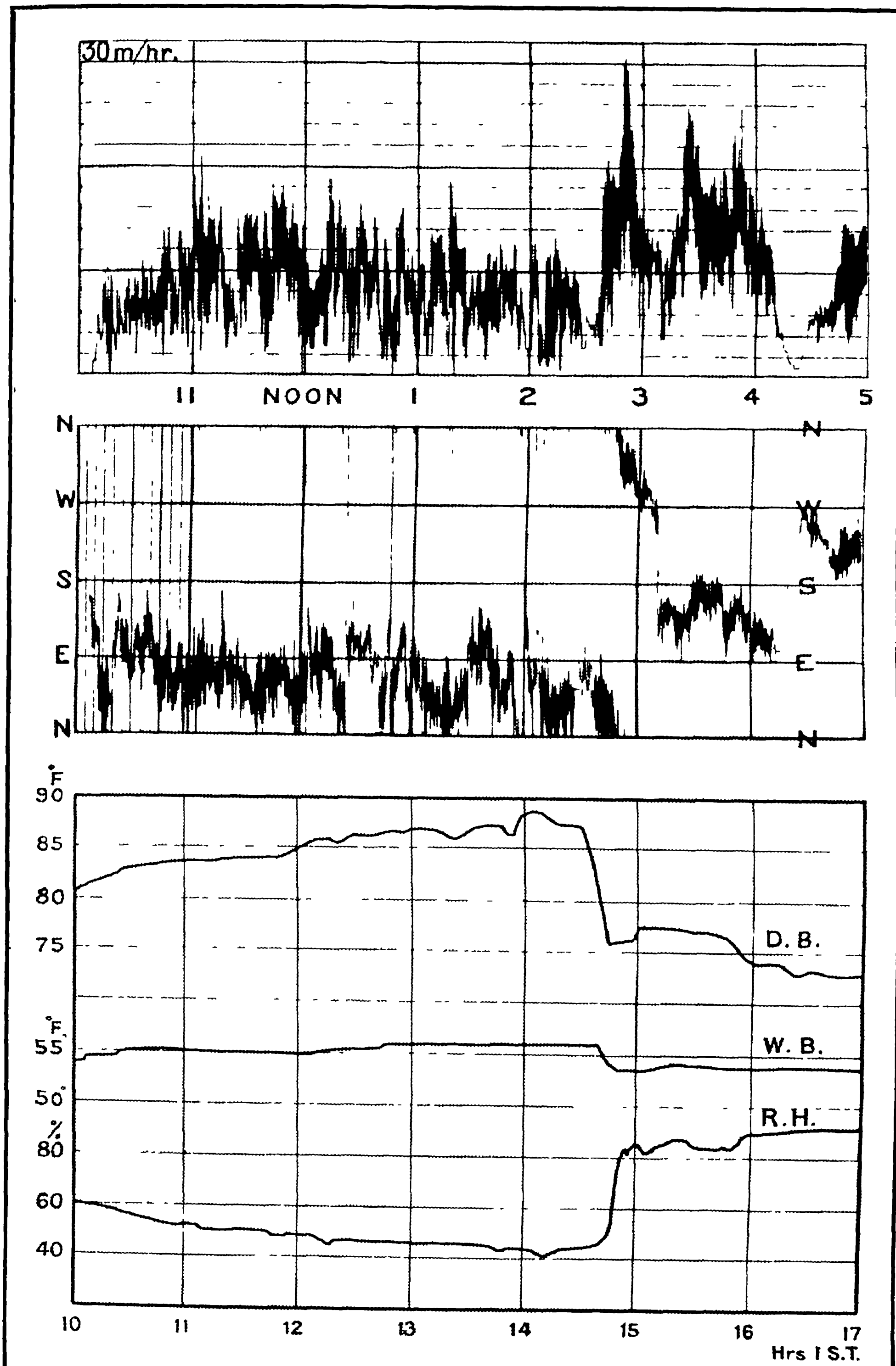

FIG 8 WEATHER AT POONA ON 12-10-1934

NO—SN6/66

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. VI, No. 66.

Normal Monthly Percentage Frequencies of Upper Winds at 4, 6, 8 and 10 Km. above Sea-level obtained from Pilot Balloon Ascents.

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NORMAL MONTHLY PERCENTAGE FREQUENCIES OF UPPER WINDS AT 4, 6, 8 AND 10 KM ABOVE SEA-LEVEL OBTAINED FROM PILOT BALLOON ASCENTS

Normal monthly directions and velocities of upper winds at practically all available heights at eight of the oldest pilot balloon observatories under the India Meteorological Department were published in Scientific Notes Vol 1, No. 7. Frequencies for heights up to 3 km from 15 pilot balloon stations were published in the form of wind-roses in Scientific Notes, Vol 1, No 8 To meet the growing needs of aviation, this was supplemented in 1930 by tables of monthly percentage frequencies at 32 stations in Scientific Notes, Vol. 2, No 17.

In connection with a study of the upper air circulation over India during the winter and monsoon (Scientific Notes, Vol 3, No 21) Banerji and Ramanathan prepared frequency tables at higher levels also, using the data of 13 stations up to the end of 1928 These were gradually extended in the Upper Air Section, Poona, and the present note contains wind frequencies at 4, 6, 8 and 10 km. at 34 stations prepared out of all available data of morning ascents up to the end of 1931. It is believed that the data will be of help to investigators of the upper atmosphere and will also meet special aviation requirements such as occurred during the Mount Everest flight in 1933 and the England-Australia Air Race in 1934. It is practically certain that progress in aeronautics will at no distant date, demand from meteorologists, information about upper winds above 3 km even for routine flights.

It may be pointed out that the limits adopted for grouping the wind speeds in these frequency tables are 5, 10, 15, 25 and 40 mps and are therefore different from those used in the previously published tables up to 3 km The two sets of speed-groups are compared below —

As used in Sc Note No 17	5 and less	6—25	26—50	51—75	>75	km./hr.
As used in present Note	<18	18—36	36—54	54—90	90—144	>144 km./hr.

Normal values of resultant directions and velocities of winds at different levels up to 8 km. have also been calculated using all data up to the end of 1931 and will soon be published in a paper on the Circulation of the Atmosphere over India and the neighbouring regions

A list of pilot balloon stations, the data of which have been incorporated in the present paper together with their geographical co-ordinates, heights above sea-level and remarks regarding dates of their opening, etc., is given below.

List of pilot balloon stations, data for which are given in this note.

No.	Station.	Lat. (N) (deg min)	Long. (E) (deg min).	Height a s l. (metres).	Date of Starting	Remarks.
1	Aden	1246	4503	10	24-10-29	Closed on 1-3-32.
2	Bahrein	2600	5035	14	2-11-27	
3	Muscat (Bait-al-Falaj)	2337	5836	24	23-9-27	
4	Gwador . .	2507	6220	10	23-9-27	
5	Karachi (Drigh Road)	2450	6704	30	31-8-25	
6	Quetta	3012	6700	1655	19-6-21	
7	Peshawar .	3402	7137	363	16-9-21	Closed between 24-4-22 and 3-12-23.
8	Lahore	3134	7421	221	20-3-18	
9	Simla	3106	7713	2130	Apr. 1913	Closed on 26-5-28. Occasional observations prior to 1913.
10	Delhi	2839	7717	210	16-11-29	
11	Ahmedabad .	2302	7238	55	19-5-28	
12	Ajmer	2627	7444	497	1-5-28	
13	Agra .. .	2710	7805	181	12-2-14	
14	Allahabad	2528	8151	111	28-2-30	
15	Patna	2537	8510	67	1-5-28	
16	Rangpur ..	2545	8918	40	25-1-29	Closed on 1-7-30.
17	Tezpur .	2637	9253	76	9-11-28	
18	Calcutta .. . (Alipore and Diamond Harbour).	2232	8820	22	23-7-23	
19	Dacca . ..	2343	9024	21	14-4-28	
20	Chittagong	2221	9153	35	31-10-28	
21	Akyab .. .	2007	9257	10	27-2-19	Closed between 20-8-20 and 12-8-21.
22	Mandalay .	2159	9608	76	19-11-28	
23	Rangoon . .	1647	9613	24	30-7-28	
24	Jubbulpore	2310	7959	402	30-7-28	
25	Ranchi . .	2323	8523	650	25-1-29	Closed on 1-7-30
26	Sambalpur . ..	2128	8401	153	17-6-30	
27	Poona	1832	7351	588	30-5-15	Closed between 31-10-15 and 5-1-25.
28	Hyderabad (Begumpet)	1726	7827	555	1-9-29	
29	Waltair .. .	1741	8321	56	24-9-28	
30	Mangalore .. .	1252	7453	40	4-6-28	
31	Bangalore	1258	7736	936	19-5-18	
32	Madras	1304	8015	13	8-4-26	
33	Port Blair	1141	9245	86	13-3-26	
34	Trivandrum ..	0831	7700	73	8-12-28	

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN.																				
	4 km										**6 km.**									
5—10	13	62	..		.		8	.	15	15	8	13	13	.	.	.	.	..	37	..
10—15		..	..		..	..	.	..	..		..	..	..	.	13	..	.	13	.	..
15—25	..		.									.		..		.		.	..	13
	8 km.										**10 km.**									
5—10	4	0	..					..	.	25	1	100					..	.		..
10—15	.	.	..	25	.		..	.	25	.	..		.		.		.	..	.	..
15—25	..	..	.	.				.	25		..	.						.		..
BAHREIN.																				
	4 km.										**6 km**									
5—10	66	3	.	.	.		..	1	11	.	23	4		.		4		..	4	..
10—15	.	..	..	..		.	.	3	35	5	..		..		.		..	..	..	..
15—25	..	..	.	.				5	23	5	.				.				48	4
25—40	.				.		..	..	6	5	.				.			..	30	4
	8 km.										**10 km.**									
5—10	4	0	.							.	..		.	.			.	.		..
10—15	.	..	.											.			.		.	..
15—25	.	.	.	.		..			50					.			.	.	.	..
25—40									25					.	..		.		..	..
>40										25		.			..	.		.	.	..
MUSCAT.																				
	4 km.										**6 km.**									
5—10	78	8						5	10	1	35	0			..		.	.	3	..
10—15	.							6	23	8			.		..		.	.	12	6
15—25			..					1	29	8					..		.	3	43	14
25—40	..														..	.		6	14	..
	8 km.										**10 km.**									
5—10	7	0									.		.	.	.	.	.	..	..	..
10—15															.			.		..
15—25			14			..			43	14							.	..	.	.
25—40		.						14	14								.	..	.	..
GWADOR.																				
	4 km.										**6 km.**									
5—10	56	4		2			2	2	16	5	23	13					.	4	9	4
10—15	..	.	..		.	.	.	.	21	13				4		.	.	4	13	4
15—25	.		..					4	13	11						.	..	4	17	4
25—40	.	..	.					.	5	4	.			..	.	.	..	.	13	4
	8 km.										**10 km.**									
5—10	12	33	..			.	.		8	..	12	50	.	..			..	..	8	8
10—15	.	.	..		.	.	.	.	25	.	.	.	.	.	..	..	..	..	..	25
15—25	..	..							8	.	.		..	..		.	.	..	..	8
25—40	..	..	..					.	8	17	..	.	.	.	..	..	.	..	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
KARACHI.																				
	4 km.										6 km									
5—10	158	6	1			1		3	6	3	111	0							1	1
10—15	.	..	.	.				8	23	7							1	2	7	4
15—25				.				6	25	7									27	11
25—40		.							6	..								3	33	6
>40		.																	4	1
	8 km										10 km									
5—10	31	0									9	0								
10—15	..								3	6										
15—25									10	6										11
25—40									12	6									22	22
>40									16	10									44	
QUETTA																				
	4 km										6 km.									
5—10	175	3	1				1	6	8	6	15	0		..	..					2
10—15		..	1					6	14	13					..			2	7	13
15—25	..		1				1	3	20	17								7	22	16
25—40										1							2		20	1
>40																			4	
	8 km										10 km.									
5—10	6	0									1	0								
10—15									17											
15—25	.								33	17										
25—40									17	17										100
PESHAWAR																				
	4 km										6 km.									
5—10	232	34	2	3	1	2	4	8	22	11	188	5	2		1	1	1	4	7	4
10—15					1			3	4	3			1				2	5	18	5
15—25	.							1	2				1					3	22	8
25—40	.	.											1					2	7	3
>40	.	.																	1	
	8 km.										10 km									
5—10	93	1	1						4		38	0							3	
10—15	.							1	2	2									3	3
15—25			3			1	1	5	31	9									16	16
25—40								2	17	11								5	26	11
>40	.	.		.					6	1									11	5
LAHORE.																				
	4 km.										6 km.									
5—10	311	15	1		.		4	12	19	11	229	2						2	5	1
10—15	.	.	..				3	6	15	7							2	3	15	5
15—25		..						1	3	3								9	30	11
25—40	.		.	.														2	8	4
>40	.		.																	1
	8 km.										10 km.									
5—10	125	2							1	1	22	5								
10—15	.		1					1	2	2										5
15—25	.						1	3	26	2									9	16
25—40		.	.					2	28	21								5	32	9
>40	..							1	4	2									18	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

SIMLA.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	335	40	1		1	6	9	6	7	9	223	4					2	4	7	2
10—15					1	4	1	1	1	6								9	17	4
15—25						1	1			1								4	23	6
25—40																			8	4
	8 km										10 km.									
5—10	114	3							2		25	4								
10—15								2	6	4									8	
15—25			1					5	18	5								4	24	8
25—40								9	28	4									28	4
>40									12	2								4	8	8

DELHI.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	34	3					.	3	9		3	0								
10—15			3					9	26	9								33		
15—25								3	29	6									33	
25—40																				
>40																			33	
	8 km.										10 km.									
5—10	1	0									1	0								
10—15																				
15—25									100											
25—40																			100	

AHMEDABAD

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	83	6	1	1		1	1	7	11	6	59	2	2	2					3	..
10—15								8	28	2								5	3	3
15—25					.			6	19	1								5	14	8
25—40								1											17	5
	8 km.										10 km									
5—10	19	0									1	0								
10—15									5	5										
15—25								11	26	11										
25—40									37	5										
>40																			100	

AJMER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	89	1	1					7	10	3	64	0								
10—15								4	20	3			2						6	2
15—25								7	31	3								3	37	6
25—40								3	3	1								6	28	8
>40																			2	.
	8 km.										10 km.									
5—10	9	0									1	0								
10—15									11										.	
15—25									22											
25—40	.	..				.	.	11	44	11									100	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AGRA.																				
	4 km.										**6 km.**									
5—10	413	5						4	13	3	326	0	1						2	1
10—15								6	24	7								2	6	2
15—25								4	21	8								5	37	5
25—40								1	2	1								2	28	6
>40																		1	3	
	8 km.										**10 km.**									
5—10	170	0							1	1	47	0							2	
10—15								1		1									2	2
15—25			1					5	19	1			2					2	15	
25—40								4	39	8								6	15	11
>40								1	15	5								4	34	4
ALLAHABAD.																				
	4 km.										**6 km.**									
5—10	25	0							12	16	13	0								
10—15									36	20									23	8
15—25									8	8								8	54	8
	8 km.										**10 km.**									
5—10	3	0									2	0								
10—15																				
15—25									67										50	
25—40									33										50	
PATNA.																				
	4 km.										**6 km.**									
5—10	72	0							4		36	0						3		
10—15								1	18	7									3	3
15—25									39	21									47	3
25—40									4	6									25	14
>40																			3	
	8 km.										**10 km.**									
5—10	2	0																		
10—15										50										
15—25																				
25—40										50										
RANGPUR.																				
	4 km.										**6 km.**									
5—10	20	0									4	0								
10—15									5											
15—25									40	10									50	
25—40									45										25	
>40																			25	

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

TEZPUR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	29	7							10	3	9	0						.	11	..
10—15									10	7									22	11
15—25								3	41	7									33	..
25—40									10									.	22	..
	8 km.										**10 km.**									
5—10	2	0																.	.	..
10—15																			.	..
15—25										50								.	.	.
25—40									50											.

CALCUTTA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	233	3						3	11	2	119	1						1	3	
10—15								2	30	10								3	17	3
15—25								1	27	9								8	45	4
25—40									1	1								3	12	.
	8 km.										**10 km.**									
5—10	24	0																		
10—15									4											
15—25								8	25											.
25—40								4	54											
>40		.							4											.

DACCA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	69	0					.		4		29	0								..
10—15			1					3	14	1									7	.
15—25									56	10									34	7
25—40			.						10									3	41	7
	8 km.										**10 km.**									
5—10	3	0															.	.		.
10—15	.		.	.																
15—25	..	.			.	..		33		33										..
25—40		.		..																
>40	.	.	..	.		.		33												.

CHITTAGONG.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	51	0	..		..		..		8	4	15	0		.	..	.	.		7	..
10—15	..	..	..	..	.		.	6	45	8				.		.	..	..	27	..
15—25	..	.	..		.	.		4	22	4									33	.
25—40	..	..		.			.												27	7
	8 km.										**10 km.**									
5—10	1	0	..	..	..	.	..	..	.			..	.	..		.	.		.	..
10—15	..	..	..	..		.	..	.		.	..		..		.	.	.		.	..
15—25	..	..	..	..	.	.	.	..	100		.		.			.	.		..	..
25—40	..	..	..	..	..	..	..				..	.	..		.	.	.		.	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

AKYAB.

4 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	300	8						5	10	6
10—15								5	27	6
15—25								3	13	7
25—40										1

6 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	228	1				.		3	7	2
10—15								4	13	5
15—25								4	46	7
25—40									7	

8 km

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	74	0							1	
10—15								8	4	1
15—25								16	34	4
25—40								1	26	[illegible]
>40										

10 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	25	4						4		
10—15								12		
15—25								20	24	
25—40								1	24	
>40									8	

MANDALAY

4 km

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	108	0						5	5	
10—15								6	31	5
15—25								3	36	2
25—40									3	

6 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	39	0								
10—15									15	3
15—25								5	28	8
25—40								10	31	

8 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	3	0								
10—15									67	
15—25										
25—40										33

10 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10										
10—15										
15—25										
25—40										

RANGOON.

4 km

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	67	33	3				1	6	17	24
10—15			1					3	7	1
15—25									1	

6 km

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	50	10					4	16	22	4
10—15								6	16	10
15—25									6	4

8 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	13	0						38		
10—15								8	23	
15—25								8	15	
25—40									8	

10 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	3	0								
10—15							33			
15—25									67	
25—40										

JUBBULPORE.

4 km

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	68	7	1				1	1	12	3
10—15			1	1					26	10
15—25								3	18	10
25—40									1	1

6 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	31	0	.					3	3	3
10—15									29	6
15—25								3	26	17
25—40									10	

8 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	9	0								
10—15									11	
15—25									22	
25—40								11	55	
>40	..	..								

10 km.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
5—10	2	0								
10—15										..
15—25									50	
25—40										..
>40		..							50	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
RANCHI.	4 km										6 km									
5—10	20	0							5	5	1	0	.				..			.
10—15		.							25	5							..		100	
15—25									35	15							..			
25—40									10								..			
SAMBALPUR.	4 km.										6 km.									
5—10	31	23	6					3	10	19	31	0	.			..	.		16	3
10—15									16	10	.								19	3
15—25									13				.					10	39	6
25—40																		3	.	..
	8 km.										10 km.									
5—10	24	0									11	0							.	.
10—15									4				.							..
15—25									29	4										..
25—40								4	50	8								9	55	
>40								..										9	27	
POONA.	4 km.										6 km.									
5—10	201	24	5	1	1			2	14	15	173	8	3				1	5	13	6
10—15			1					4	13	8			3				.	6	20	10
15—25								1	4	3			1					2	16	7
25—40																			1	1
	8 km										10 km.									
5—10	115	3					1	2	5	5	45	2						4	4	
10—15			2						14	8							2	4	24	7
15—25			1					5	34	7								7	11	4
25—40								3	8	3								9	16	2
HYDERABAD	4 km										6 km.									
5—10	58	40	3	2			2	5	17	5	51	20						2	8	4
10—15			3					5	5	10			2				2	12	20	10
15—25										2									6	6
	8 km										10 km.									
5—10	37	0						3	11		18	0						6		.
10—15								8	13										6	
15—25								11	35	8								6	44	
25—40		.							5	5									28	11
WALTAIR.	4 km.										6 km.									
5—10	80	34	4	1		3	1	5	19	13	59	14	2					7	17	12
10—15			5	1				1	6	5								8	19	3
15—25								1	1									2	10	5
25—40																			2	
	8 km										10 km.									
5—10	24	0							4		6	0								:
10—15								17	13	4								17	67	.
15—25								17	46										17	
25—40																				

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JANUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
MANGALORE.																				
	4 km.										6 km.									
5—10	72	49	8	8	10	8	1	6	.		33	45	6	3	.	9	6	6	9	6
10—15	..	.	.	4	.	.	.	.	6				3					3	.	.
15—25	..	.		..	.		..			.	.							3		..
	8 km.										10 km.									
5—10	12	33	8		.	8	8	8		17	3	33		.					33	.
10—15	..	.	8		.		.	.		8						..			.	..
15—25	..	.	.	.				.	.	.								33		..
BANGALORE.																				
	4 km.										6 km.									
5—10	318	50	3	6	45	4	1	5	5	1	238	37	4	7	6	5	2	5	6	4
10—15	.	.	1	3	5		.	1	.			..	3	4	3	1		3	5	2
15—25	.	.	.				.		.				1	1	.	1			2	1
	8 km.										10 km.									
5—10	162	25	4	2	4	2	2	4	7	3	83	11	1	2	2	2	2	6	6	2
10—15		.	4	4	3	1		5	7	1			2		2		4	11	8	5
15—25			2	1	1			2	10	2		..			1		2	16	12	1
25—40	..		..	.			1	1	.									1	1	.
MADRAS																				
	4 km.										6 km.									
5—10	99	63	7	7	7	4	1	3	4	1	80	49	7	3	3	5	5	4	3	7
10—15	.	.	1	.	1	1					.		4	1		3	1	3	1	3
	8 km.										10 km.									
5—10	44	34	2	.	5		2	11	9	2	22	14	.		5			9	32	5
10—15	..		5	2	.	..	..	2	9	5								9	9	
15—25	..	.		2				2	5	2							5	5	5	5
PORT BLAIR.																				
	4 km										6 km.									
5—10	85	65	1	6	15	8		.		.	66	44	8	17	8	5	1	3	3	1
10—15	..		1		1	1			.		.		1		6	1				..
15—25	..			1	.						.	.			1					
	8 km.										10 km.									
5—10	43	33	14	16	7	5	5	2	2	7	20	30		5	5			15	10	15
10—15	.	.							2	2							10			5
15—25	.	..	2	.	2										.					5
TRIVANDRUM.																				
	4 km.										6 km.									
5—10	63	30	3	5	21	11	10	..	..	3	47	11	4	11	11	4	4		2	2
10—15	..	.	2	5	3	5	.	2					2	6	23	4	6	2	2	..
15—25	..		.	2			.	.	.	.	.				2	2				.
	8 km.										10 km.									
5—10	10	10	.	.	10	10	..	.	.	..	1	0	.	.		.				
10—15			..	10	20	10	10	.	..	10	.			.			.	100		.
15—25	..	.	.	..	..	.	..	10	..	..	.	.	..	.	.	.		.	.	.

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY.

ADEN.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	31	42		13	13	10		.	3	10
10—15									3	3
15—25			3					.		

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	20	55	.	5	5	5	5	10	..	5
10—15	.			..			.	5	..	.
15—25	.						.	..	..	5

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	8	50					..	25		
10—15		.	..	13			.	.	.	
15—25		.							13	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	4	0		.		.	..	..	25	25
10—15		..	.	..	..	.	.	..	..	25
15—25	.	..	.	..	..		.	..	25	..

BAHREIN.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	53	6						6	4	2
10—15	..							4	19	9
15—25			4			.	.	6	28	6
25—40							..	..	6	2

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	19	0	.		.		.	5	..	
10—15	..		.	..				5	5	.
15—25	.			.	..		.	..	26	21
25—40		..	..	..	..	.	..	..	32	5

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	1	0								
10—15	..	.	.							
15—25		.	.			..			.	.
25—40				.			.	.	100	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	.		.		..	.	.	.		..
10—15		..		..	..	..	..	..	.	..
15—25	.	..	..		.	.	..	..	..	..
25—40	..	..	..	..	.	.	..	..	..	..

MUSCAT.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	64	11		.	.		2	5	6	6
10—15			2	2			.	3	17	9
15—25				.				.	23	11
25—40						.		..	2	.

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	26	0	.	.	..	.	..	.	8	..
10—15	..	..	.	.				12	35	4
15—25			4	.	.		.	4	19	15
25—40	..	..	..		.		.	..		.

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	7	0								.
10—15									14	
15—25							.		14	28
25—40									14	14
>40									14	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10		.			..	.	.		.	.
10—15	.	..	.				.	.	.	..
15—25	.					.	.		.	.
25—40			.	.		..	.	.	.	.
>40				.		..	.		.	

GWADOR.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	62	8	2				3	2	6	2
10—15		.	3					2	19	10
15—25	.								26	11
25—40									6	

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	32	3			.		..	.	3	3
10—15			..			.		...	9	3
15—25	..			.	..			.	37	19
25—40	.	..		.		..		.	9	13

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	6	0	..	..	..	..	.	.	..	..
10—15	.		.	.		.			.	..
15—25		.		.		.	..	.	50	17
25—40	..			.	..	.	..	..	..	33

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	..	..	..	.	.	.	.	..	..	.
10—15	.	..	..	..	..	.		..	..	..
15—25	..	..	..	..	..	..	.	..	..	..
25—40	..	..	..	..	..	..	.	..	..	.

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
KARACHI.																				
	4 km.										6 km.									
5—10	136	5	1	1				4	15	7	106	0						1	4	2
10—15			2					1	23	8			1					3	8	3
15—25								3	19	7			1				.	2	43	8
25—40									3	1							.		21	3
	8 km.										10 km									
5—10	36	0							3		6	0								
10—15									3	3										
15—25			3					3	19	3									17	
25—40									53	3									67	17
>40									6	3										
QUETTA.																				
	4 km.										6 km.									
5—10	177	5					1	3	8	5	54	4							6	4
10—15							1	6	27	12								2	9	
15—25								4	12	12								9	31	13
25—40										4									15	4
>40										1									2	2
	8 km.										10 km.									
5—10	15	13			.						5	20				.				
10—15								7	7	7										
15—25									20											
25—40								7	33									.		
>40								..	7										60	20
PESHAWAR.																				
	4 km.										6 km.									
5—10	194	35	2	2	1	1	3	7	16	10	164	4	2	1		1		5	9	2
10—15			1			1	3	3	6	6			1			..		6	15	5
15—25								3	1	3			1				1	6	21	10
25—40																	1		4	5
>40	.	.																		1
	8 km.										10 km.									
5—10	95	1							1	1	38	0								
10—15			2					5	4	3									11	3
15—25			1					7	27	5			3					3	8	8
25—40									20	9								3	21	8
>40							2		6	3									24	11
LAHORE.																				
	4 km.										6 km.									
5—10	269	12		1		1	4	7	19	9	173	1					2	3	1	1
10—15							1	4	12	12						1	6	12	3	1
15—25								1	7	6			3				2	25	20	
25—40													1				3	10	4	1
>40	.	.														.			2	
	8 km.										10 km.									
5—10	90	3						2	2	1	17	6		.				.		..
10—15								2	2	2		.							12	
15—25	..							6	11	8								.	18	12
25—40			1					3	22	14									29	12
>40								1	13	4						.		6	6	

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and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
SIMLA.																				
	4 km.										**6 km.**									
5—10	324	35	1			4	7	8	10	13	204	4						4	7	1
10—15		..			.	1		1	3	9								7	9	5
15—25		..				1				5								8	24	12
25—40						..					.								12	5
	8 km.										**10 km.**									
5—10	113	1					..		2		30	3							3	3
10—15							1	1	1	1			`						3	3
15—25				..	..			3	13	7									17	3
25—40				..		..		6	41	9								3	20	3
>40						..	.		11	4			3					3	23	7
DELHI.																				
	4 km.										**6 km**									
5—10	38	5						8	13	5	23	0								
10—15							..	3	32	18								4	9	9
15—25							..		11	3									39	22
25—40								3		..									17	
	8 km.										**10 km.**									
5—10	7	0									1	0								
10—15																				
15—25									29	14										
25—40									57											
>40																			100	
AHMEDABAD.																				
	4 km.										**6 km.**									
5—10	70	3	6					4	11	9	39	0		..					10	5
10—15		.	1					1	24	4			3						26	8
15—25								7	20	4								5	26	5
25—40						.	..	..	4									3	10	.
	8 km.										**10 km.**									
5—10	8	0							13		1	0								100
10—15										..										
15—25			.						37	..										
25—40									25	13										
>40								.	13											
AJMER.																				
	4 km.										**6 km**									
5—10	78	5	.			.		6	3	6	51	0							.	2
10—15			3					8	28	12									8	8
15—25								9	10	5								4	35	12
25—40		.						.	4	1								2	27	2
	8 km.										**10 km.**									
5—10	4	0				..											.	..	.	..
10—15																		..	..	.
15—25	.							..	50	25								.	.	.
25—40	..							..	25											..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY.

AGRA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
					4 km										6 km.					
5—10	378	3						2	9	4	292	1							1	
10—15			1					4	25	10							.	1	5	2
15—25								5	22	11								3	33	12
25—40								1	3	1								2	29	7
>40																		.	2	2
					8 km.										10 km.					
5—10	151	0							1		31	0								
10—15								1	1									.	3	
15—25								1	14	7								3	3	3
25—40								2	35	12								6	32	6
>40								1	20	3								.	36	6

ALLAHABAD.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
					4 km.										6 km.					
5—10	19	0				.					2	0	..							
10—15									5											
15—25									68	5	.	.	.							
25—40									23									.	100	

PATNA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
					4 km.										6 km.					
5—10	57	2	2						4	4	33	0								3
10—15									21	14								.	3	12
15—25									35	12									36	12
25—40									7										27	3
>40																		3		
					8 km.										10 km.					
5—10	7	0											.							
10—15												..								
15—25									14											
25—40			14						14	29										
>40									29											

RANGPUR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
					4 km.										6 km.					
5—10	35	6	3	3	6				3	6	15	0							7	7
10—15									9	3								.	13	13
15—25			3						49	11								.	33	7
25—40																			7	7
>40																		7		

TEZPUR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
					4 km.										6 km.					
5—10	24	21							8	8	11	0					.		9	18
10—15						.	.	4	13						.			.	9	
15—25									37	4					.				45	
25—40									4	.								.	9	.
		.						.										.	9	
					8 km.										10 km.					
5—10	1	0			..	..			.	.		.		.	.	.	.	.	..	..
10—15		.				..	.	.	.								..		..	
15—25		..		.					..	100							..	.	.	

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and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
CALCUTTA.																				
	4 km.										**6 km.**									
5—10	174	2	1				1	2	10	6	74	3							1	3
10—15			1					1	20	14			1					1	8	5
15—25									20	19								3	45	5
25—40								1	1	2									22	1
>40																			1	
	8 km.										**10 km.**									
5—10	1	0																		
10—15																				
15—25									100											
DACCA.																				
	4 km.										**6 km.**									
5—10	41	10							7		15	0								
10—15									24										7	
15—25									49	2									33	7
25—40									7									7	47	
CHITTAGONG.																				
	4 km.										**6 km.**									
5—10	44	2							11	7	14	0								
10—15									39	9										
15—25								2	25	5								7	43	14
25—40																			29	7
AKYAB.																				
	4 km.										**6 km**									
5—10	265	3	1					6	15	9	180	1						2	3	2
10—15								2	30	10			1					2	14	2
15—25								1	12	6			1					4	47	7
25—40									2	2								1	13	1
	8 km.										**10 km.**									
5—10	59	2						2	2		22	0								
10—15								2	7	2								5	5	5
15—25								3	39	2								9	18	5
25—40								2	32	2								9	27	
>40									3										18	
MANDALAY.																				
	4 km.										**6 km.**									
5—10	80	4						4	13	1	26	0								
10—15								3	37	1										12
15—25								6	26	5								4	54	4
25—40																			27	
	8 km.										**10 km.**									
5—10	1	0																		
10—15																				
15—25																				
25—40									100											

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
											RANGOON.									
					4 km.										**6 km.**					
5—10	56	29	2				4	7	20	4	40	15	3				3	7	13	5
10—15								5	23	4								7	23	7
15—25								2	2										17	
					8 km.										**10 km.**					
5—10	11	9						28	18		4	0		.	.	.	.	.		
10—15								9	18	..					..	.	.			..
15—25								9		9					.			50	25	.
25—40																		25		.
											JUBBULPORE.									
					4 km.										**6 km.**					
5—10	66	3	3					2	12	11	28	0		.						4
10—15			2					2	17	8			.	.					11	7
15—25								3	27	6									46	21
25—40								2	5								.		11	
					8 km.										**10 km.**					
5—10	1	0																		
10—15	.																	.		
15—25																				
25—40	..								100											
											RANCHI.									
					4 km.										**6 km.**					
5—10	38	3							13	5	17	0				.	.		6	
10—15									24	26									6	6
15—25									13	13									35	41
25—40									3					..					6	
					8 km.										**10 km.**					
5—10	2	0																		
10—15																				
15—25									50	50										
											SAMBALPUR.									
					4 km										**6 km.**					
5—10	25	0					..		24	4	24	0							..	..
10—15				..					28										4	
15—25									40	4								4	67	4
25—40																			21	
					8 km.										**10 km.**					
5—10	10	0	..							.	5	0							.	
10—15								10	.	s..									40	..
15—25																			20	.
25—40									80									20	20	
>40	..								10					.						

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
POONA.																				
	4 km.										**6 km**									
5—10	186	19	9	1	1		2	3	17	8	151	3	2	1			1	5	8	9
10—15			4	1				9	13	6			4				1	1	15	12
15—25				1				2	4	1			1					2	28	5
25—40																			4	..
	8 km.										**10 km.**									
5—10	84	1		.				1	4	2	25	0								..
10—15			.				1	2	13	10	.								12	8
15—25								6	39	7							.		28	12
25—40									7	6									32	8
HYDERABAD.																				
	4 km.										**6 km.**									
5—10	54	26	4	4				11	17	4	44	7	2					2	9	9
10—15			6					2	17				5					5	16	7
15—25									11				2					7	20	5
25—40																			5	.
	8 km.										**10 km.**									
5—10	26	0							12	4	8	0								
10—15									23	4									13	.
15—25									46	8			13					13	25	13
25—40									4										25	
WALTAIR.																				
	4 km.										**6 km**									
5—10	64	20	6	3				5	27	16	38	8						3	3	3
10—15			5					3	9	3									29	8
15—25									3									11	34	3
	8 km										**10 km**									
5—10	8	0							13		1	0								
10—15									25											
15—25								13	13											.
25—40								25	13										100	.
MANGALORE.																				
	4 km.										**6 km.**									
5—10	45	50	..	4	11	2	2	4	4	2	23	26		4	11	2	2	4	4	2
10—15			.	2				2	7					2				2	7	
15—25					2			.	4	2					2				4	2
	8 km.										**10 km.**									
5—10	1	.				.												.		
10—15	..	..																	.	.
15—25	..	..	..						100										..	

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in FEBRUARY.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
BANGALORE.																				
	4 km										6 km.									
5—10	317	48	2	11	9	4	2	2	5	2	268	35	6	8	5	3	3	5	7	5
10—15			1	4	5			1	1				2	3	3	2	1	1	4	1
15—25				1					1					1					2	
	8 km										10 km.									
5—10	191	32	5	6	3	2	4	4	6	8	106	23			3	2	5	8	8	2
10—15			3	1	1	1	1	2	8	4			1	1		1	2	4	10	7
15—25			3		1				5	3			3					6	9	1
25—40								1									.		2	
MADRAS.																				
	4 km.										6 km.									
5—10	105	54	6	15	1		6	2	4	2	74	34	7	1			3	11	8	11
10—15			3	2	1	1	1	2	1				4	1			3	1	7	4
15—25				.									1					1	1	..
25—40																			1	..
	8 km.										10 km.									
5—10	37	14	5	3				5	14	11	15	13					7	7	20	
10—15			5				3	3	5	11								7	20	
15—25	.		3					3	11	5									7	7
25—40		.																	13	
PORT BLAIR.																				
	4 km.										6 km.									
5—10	102	64	3	5	8	2	1	2	4	2	87	50	2	2	2	3	5	9	6	3
10—15			.		1	3	1	1	1	2			1	1	1			1	5	..
15—25								1						2				2	2	1
25—40											..									
	8 km										10 km.									
5—10	52	35	4	2	8		12	8	6	.	31	35	3			6	13	3	6	
10—15			2				4	2	2	4					3		10	10		.
15—25			2			2		2	6				3						3	..
25—40	.			.						2		.							3	.
TRIVANDRUM.																				
	4 km.										6 km.									
5—10	62	24	2	6	24	19	5	3	2	3	43	5		2	28	12	5	.	7	
10—15	..	.	2	2	3	2			2			.	2	5	23	7	5	..	..	.
15—25		.	.	.						2		.		.		.	.		..	
	8 km.										10 km.									
5—10	9	0			22						1	0		.		100			..	..
10—15		..			11	22	11			.	.			.			..	.	..	..
15—25	..	..			22	11				.				..			.	..	..	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN.																				
	4 km										6 km.									
5—10	26	58	8	8	12	4					18	33	6			6	6	6	22	6
10—15				4	4					4						6			6	6
	8 km										10 km.									
5—10	9	33			11			11	22		6	33								..
10—15								11										17	33	
15—25										11									17	..
BAHREIN.																				
	4 km.										6 km									
5—10	51	10	2				2	2	22	10	23	0	4					4	4	.
10—15								8	14									17	17	9
15—25			2					6	22	2									26	4
25—40																			13	
	8 km.										10 km.									
5—10	7	0																		
10—15									14											.
15—25								28	14	14										
25—40								14	14										.	.
MUSCAT.																				
	4 km.										6 km									
5—10	52	24	2		2			8	10	11	37	3						11	5	8
10—15							2		24	3								8	22	19
15—25									6	8									16	3
25—40																		.	5	
	8 km.										10 km.									
5—10	11	0									4	0								
10—15									36											
15—25																			75	
25—40									36	27									25	
GWADOR.																				
	4 km.										6 km									
5—10	59	27		2				5	12	12	30	0	3						3	13
10—15			3					3	12	8								5	8	13
15—25									12	2			3						28	15
25—40										2									3	3
>40																			3	3
	8 km.										10 km.									
5—10	9	0																	.	.
10—15	.	.							22										.	..
15—25									44			..	.							
25—40	.								22	11								.	.	

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

KARACHI.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	145	19	3	1				4	15	10
10—15			1					3	10	6
15—25			1					1	20	6
25—40									1	
>40										

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	107	4	2					2	3	5
10—15								3	14	7
15—25								2	28	12
25—40			1					2	13	3
>40									1	

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	35	0							6	
10—15										3
15—25								3	29	9
25—40									29	14
>40								3	6	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	8	0								
10—15										
15—25										
25—40									50	13
>40									38	

QUETTA

4 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	230	15	1				1	7	14	9
10—15							1	5	10	11
15—25			1					1	10	10
25—40										2

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	86	6	2					3	14	8
10—15									16	7
15—25			1					3	21	8
25—40									7	2

8 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	25	8							12	4
10—15				4				8		4
15—25								4	40	12
25—40									4	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10										
10—15										
15—25										
25—40										

PESHAWAR

4 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	215	23	4	2	1		2	7	20	13
10—15			1				2	6	8	6
15—25								1	2	1
25—40										

6 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	190	8	2	1	1		1	4	7	7
10—15			2		1		1	4	14	9
15—25			2					5	19	6
25—40								1	6	2

8 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	100	5						2	4	3
10—15								2	12	12
15—25						1		1	25	11
25—40			1					1	10	5
>40								1	3	1

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	51	2						2	8	4
10—15								4	2	2
15—25				2				2	20	6
25—40			2					4	18	10
>40									10	4

LAHORE

4 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	340	18	1		1		2	5	15	13
10—15			2				1	6	14	11
15—25								2	4	5
25—40										

6 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	235	4	1				1	3	13	5
10—15								5	17	8
15—25								4	18	9
25—40								1	6	4

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	136	1						2	3	7
10—15				1				4	11	6
15—25								4	24	8
25—40								2	15	10
>40		.							1	1

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	57	0						2	4	2
10—15								2	5	9
15—25								5	28	9
25—40								2	23	4
>40									8	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
SIMLA.																				
	4 km.										**6 km.**									
5—10	359	39	1	1	1	3	3	7	9	13	255	15		1	.		2	5	12	7
10—15			.			1	1	1	4	9			1					3	12	7
15—25								1	2	4							2	3	16	9
25—40										1									2	3
	8 km.										**10 km.**									
5—10	159	4						1	6	2	67	3						3	1	1
10—15			1		1			1	9	6			3						9	6
15—25			1					5	21	9			1	1					22	9
25—40								1	17	9								1	19	10
>40									5	2									7	
DELHI.																				
	4 km										**6 km.**									
5—10	36	3	3				..	6	11	19	11	9						9		.
10—15								17	11	6								9		9
15—25									17	8								18	18	9
25—40																			9	9
	8 km.										**10 km.**									
5—10	1	0																		
10—15										100										.
AHMEDABAD.																				
	4 km.										**6 km.**									
5—10	80	25	4			1	1	11	17	5	62	16	3			2		2	11	10
10—15			1				1	10	9	4								2	15	8
15—25								5	4	1			2					3	19	6
25—40																			2	..
	8 km.										**10 km.**									
5—10	24	4						8	13	8	4	0								.
10—15									4	17									25	25
15—25	.							4	25	4									50	..
25—40			4						4											
>40				2					4										.	..
AJMER.																				
	4 km.										**6 km.**									
5—10	89	16	2				3	6	13	10	57	12	2				..	5	7	4
10—15								6	11	7								2	18	7
15—25			1					4	13	1								9	16	9
25—40		.							3	2									5	4
>40																				2
	8 km.										**10 km.**									
5—10	14	7						7	7	7	4	0								..
10—15		.							21	7									25	..
15—25	.		7						14	14								..	75	..
25—40	.	.	.						7								.		.	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

AGRA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	406	5	1					2	13	9	325	2	1					1	5	4
10—15			1					5	19	14			1					1	9	7
15—25								5	16	8								4	38	8
25—40																		1	14	4
	8 km.										10 km.									
5—10	190	1	1					1	3	3	79	1		1					1	4
10—15									7	3			1						6	5
15—25			1	1				2	28	9			1						23	9
25—40			1					1	27	3								1	19	3
>40									11	1									23	1

ALLAHABAD

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	37	1						3	3	11	19	0	5						11	11
10—15			3						19	14			5						5	11
15—25									32	14									37	11
25—40																			5	
	8 km										10 km.									
5—10	4	0								25	1	0								
10—15									25											100
15—25									25											
25—40									25										..	.

PATNA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	54	6	6						7	6	25	4							4	12
10—15			2						11	17									8	20
15—25								2	21	21									8	24
25—40										4									20	
	8 km.										10 km.									
5—10	10	0								.	4	0								
10—15									10											
15—25								10	40	30										25
25—40									10										75	

RANGPUR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	29	24		3		3			14	3	11	0	0						..	..
10—15									7	17								9	36	9
15—25	.								21											18
25—40										7									9	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
TEZPUR.																				
	4 km.										**6 km**									
5—10	17	35						6	6		5	0								
10—15				6			6		6										20	
15—25								6	24										80	
25—40									6											
	8 km										**10 km**									
5—10	1	0																		
10—15																				
15—25																				
25—40										100										
CALCUTTA.																				
	4 km										**6 km**									
5—10	220	10	1					2	13	12	135	4	1					2	5	6
10—15								2	14	20			1					4	24	10
15—25									13	11								1	24	7
25—40																		1	7	1
	8 km.										**10 km.**									
5—10	30	3							3	10	7	14							14	
10—15									10	7									43	
15—25			3						33	10									29	
25—40									17	3										
DACCA																				
	4 km										**6 km.**									
5—10	42	17		2					10	19	23	22							9	9
10—15									14	10			4						4	4
15—25									19	5									39	
25—40									2	2									9	
	8 km.										**10 km.**									
5—10	7	0							14	0	4	0								
10—15									14	14									25	25
15—25								14	43											..
25—40																			50	
CHITTAGONG.																				
	4 km.										**6 km.**									
7—10	48	27	2	2	2			8	17	10	14	7							14	14
10—15								2	13	4									14	21
15—25									10									7	14	7
25—40										2										
	8 km.										**10 km.**									
5—10	2	0							50											
10—15																				
15—25			50																	

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AKYAB.																				
	4 km.										**6 km.**									
5—10	295	17					1	8	23	14	205	4	1		.		.	2	12	2
10—15			1					2	14	8					..			7	23	6
15—25								1	5	3				.				6	24	8
25—40			1															1	3	
	8 km.										**10 km.**									
5—10	80	3							4	1	15	0								
10—15								1	7											7
15—25				1				11	37	10									13	
25—40								3	21									27	47	
>40																			7	.
MANDALAY.																				
	4 km.										**6 km.**									
5—10	57	21	2	.		.		5	12	4	19	5							5	11
10—15		.		.				11	28	11			.						26	
15—25						.			5	2									37	
25—40																			11	5
RANGOON.																				
	4 km.										**6 km.**									
5—10	51	41	2				2	14	22	4	27	7				4	4	11	26	7
10—15								6	8									4	19	
15—25							2											4	11	4
	8 km										**10 km.**									
5—10	2	0																		
10—15								50												
15—25									50				.							
JUBBULPORE.																				
	4 km										**6 km**									
5—10	53	9							23	19	27	15							15	19
10—15		..	8						17	8									7	11
15—25								2	6	9								4	19	4
25—40																			7	
	8 km.										**10 km.**									
5—10	3	0						33		33								.		.
10—15	..						.		33						.			.	.	.
RANCHI.																				
	4 km.										**6 km.**									
5—10	43	7	5						7	14	19	5						5	5	
10—15			2						14	21									26	16
15—25	.								12	19				.			.		5	32
25—40	.	.				.								.	.				5	
	8 km.										**10 km.**									
5—10	4	0							25	.	1	0						.	.	
10—15			..						25									.	..	
15—25					.				50										100	

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
SAMBALPUR.																				
	4 km.										6 km.									
5—10	30	7	7					3	10	17	28	0			.			4	11	11
10—15			3						17	17			4				.	4	7	
15—25									17	3								4	39	7
25—40																			11	
	8 km.										10 km.									
5—10	9	0							11	11	3	0							.	.
10—15	.	..	11	.		.			11											33
15—25	.		..					11	11											.
25—40			.		.			11	22									33	33	..
POONA.																				
	4 km.										6 km.									
5—10	208	40	3	3			6	12	10	7	179	14	5	1			1	5	15	9
10—15				1				6	2	4			2	1				2	19	8
15—25			.					1	1									2	9	6
25—40			.	..														1	1	.
	8 km.										10 km.									
5—10	114	8						3	6	4	48	8						6	10	2
10—15							1	4	14	6				.				2	10	.
15—25								9	25	12								17	15	
25—40									7	2									13	10
HYDERABAD																				
	4 km.										6 km.									
5—10	57	42	16		..			5	7	12	43	26	5					9	9	5
10—15			7						5						.			2	16	9
15—25			4															2	14	2
	8 km.										10 km.									
5—10	27	11						11	7	7	6	0				.		17	17	17
10—15			.						19	4							.		17	
15—25	..							15	15	4									33	
25—40		.						4	4										.	.
WALTAIR																				
	4 km.										6 km.									
5—10	59	46	7	8				.	10	12	38	39	3	.				8	13	3
10—15	..		3	5				3		3			3					11	5	..
15—25			2							.							..	5	11	.
	8 km.										10 km.									
5—10	17	12	6					6	12	6	6	0						.	17	17
10—15								6	24	6			17					17		
15—25	..	.	.	..				12	12									17		17

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MARCH.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
MANGALORE																				
	4 km.										6 km.									
5—10	39	49	5	8	10	3		3	3		18	44	6		6				22	17
10—15			3	5	8															
15—25	.			5										6						
	8 km										10 km.									
5—10	3	0								33	1	0							100	
10—15																				
15—25	.			33				33												
BANGALORE																				
	4 km.										6 km									
5—10	363	42	1	11	11	4	1	1	1	1	281	44	4	6	5	6	3	2	7	5
10—15			1	12	8	1				1			2	2	3			2	2	1
15—25	.			2	1									1	1				1	1
	8 km.										10 km.									
5—10	197	28	4	4	3	2	2	4	5	5	105	26		1	2	1	1	5	9	6
10—15			5	1	3	1	3	3	11	3			1	1	1	2	2	4	14	1
15—25			3					2	6	4			1	1			3	6	9	3
25—40					1			1	1								1	1		
MADRAS																				
	4 km.										6 km									
5—10	130	55	6	14	9	4	2	1		2	98	44	2	8	14	7	5	2	7	4
10—15			1	5	1	1							2	2		1		1		
15—25				1																
	8 km										10 km									
5—10	43	30		9	5	7	7	7	9	14	15	33	7				7	13	13	
10—15	.		2	.	5		2	2							13			7		
15—25																				7
PORT BLAIR																				
	4 km										6 km.									
5—10	128	52	2	5	14	9	3	3	4	2	109	38	3	8	14	13	2	3	3	4
10—15					3	1		1						3	4	3	1		3	
15—25																1				
	8 km										10 km									
5—10	54	28	6	11	11	6	9		9		32	44			3	6		3	9	
10—15			2	2	6	4	4		2	2				3	9		3	3	6	
15—25					2														9	
TRIVANDRUM																				
	4 km										6 km.									
5—10	59	15	5	7	25	7	10		2		24	21			17	8	4			
10—15			2	3	5	7	5	3					4	4	17	21				
15—25						2		2												4
	8 km.										10 km.									
5—10	4	0			50				25		1	0		100						
10—15						25														.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN																				
	4 km										**6 km.**									
5—10	28	39	7	18	11					7	17	59		6					6	..
10—15				7	11										6		6			6
15—25																6		.	6	..
	8 km										**10 km.**									
5—10	8	25					13				3	33						.	.	.
10—15				13					13	37								33		..
15—25																	.			33
BAHREIN																				
	4 km.										**6 km**									
5—10	69	25	4			3	3	4	9	12	31	26			3			6	10	[illegible]
10—15			1					3	13	1			3				3	10	10	6
15—25						1	1	6	6	3			3				3		6	[illegible]
25—40								1	3										.	
40																3				
	8 km										**10 km**									
5—10	15	0						13	7	7	8	0							.	..
10—15								20	20	13									13	..
15—25							7		7									25	37	13
25—40																			13	.
40			7																.	..
MUSCAT.																				
	4 km										**6 km.**									
5—10	81	43	2	2	7	2		2	9	6	53	17	8		2			13	32	2
10—15				2		1	.	2	11	6			4					2	8	2
15—25										1							.	2	4	6
	8 km.										**10 km.**									
5—10	18	0	11						11	6	9	0	11						11	..
10—15								6	28	11			11				11	11		..
15—25									11	11			11						33	.
25—40									6										.	..
GWADOR.																				
	4 km.										**6 km.**									
5—10	64	44	6	5		2	8	3	5	5	49	20	4	2				14	12	14
10—15			5					3	8	2			4					4	8	
15—25			2					2	3									8	6	
25—40																				2
	8 km.										**10 km**									
5—10	15	13	7							13	6	0							17	
10—15									40								.	..	17	17
15—25								7	13										50	
25—40									7							.		.	.	.

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
KARACHI.																				
	4 km										6 km.									
5—10	133	30	6	5	2	1		5	10	8	97	15	3				.	4	9	11
10—15		.	2	2				1	9	3			1			.		5	12	4
15—25								4	10	4			2			.		5	10	8
25—40			.						2							.	..	2	5	1
	8 km.										10 km.									
5—10	35	6							14	6	13	8						.	8	.
10—15			3						9	3								8	23	
15—25								3	14	23					.	.		8	..	15
25—40								3	14	3	.					..			8	23
QUETTA.																				
	4 km.										6 km.									
5—10	228	22	3			1	1	5	17	10	98	10	1	1	1	1	1	9	11	6
10—15			3				1	1	7	13							1	9	12	11
15—25	.						.	2	4	8			2			.	.	5	8	5
25—40													2			.		2	.	..
	8 km.										10 km.									
5—10	36	3			3		3	3	3	3	2	0		.		.	.		..	..
10—15								6	6	14		.	..			.			..	50
15—25			3					8	17	11		.					.	.	50	.
25—40								6	11							.			.	.
40	..								3			..						.	.	..
PESHAWAR																				
	4 km										6 km.									
5—10	226	23	3	1		1	4	8	22	13	180	13	3	1	1	1	2	6	15	7
10—15	..		.				2	3	8	7			1		1		1	4	17	9
15—25		.	.					1		1			1				1	2	11	6
	8 km.										10 km.									
5—10	104	11		1	1	1	2		9	3	54	7	2	.			4	2	11	2
10—15		.	4		1	1		3	7	11			2	.				4	4	2
15—25			1					2	25	12			4		2			6	13	7
25—40								1	3	4								2	19	6
40	.				.	.						.			.	.	.	.	2	..
LAHORE.																				
	4 km.										6 km.									
5—10	356	21	3			1	2	5	11	19	269	8	2	.	.	.		4	14	9
10—15	.		3				2	4	12	13		.	2	.	.	..		5	16	12
15—25								1	3	3			1		.		..	3	13	7
25—40						.			.							.			2	..
	8 km										10 km.									
5—10	175	4	1		.	.	1	2	6	3	78	4	1	.	1	.	.	1	8	..
10—15	.	.	1	1	1			5	15	5		.			.	.	..	1	10	4
15—25	.		1	1				3	19	15	.	.	4	.	.	..	.	4	27	4
25—40			1	.		..			12	4	.	.			..	..	.	..	21	6
40	..	..	.	..	.	.		..	.	..	..	..	..	.	..	.	..	..	3	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

SIMLA

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.																			
5—10	378	38	1		1	4	3	3	9	21	265	10	2	.	.		2	10	18	9
10—15		.	.	.	..	..	1	2	1	12							2	4	12	8
15—25							1	1		3								3	13	6
25—40			.								.							.	1	1
	8 km.										10 km.									
5—10	176	7	2				1	3	7	5	96	5			.		.	.	3	2
10—15				.			1	7	15	6	..		.					4	11	7
15—25								5	21	4			2					5	29	3
25—40								2	8	3								1	17	3
40								1	1							.		1	4	1

DELHI

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	33	6	3					6	18	24	19	5						11	5	11
10—15				..	..	..		3	27	12			.	.					11	21
15—25													..	.				11	16	11
	8 km.										10 km.									
5—10	6	0	.								2	0								
10—15										17					.				.	.
15—25	.								33	50								.	.	50
25—40											.	.		.		..		.	50	..

AHMEDABAD

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	77	25	4				3	12	21	6	48	10	2					6	17	10
10—15								12	9				2				2	8	23	6
15—25							1	6	1										8	4
	8 km.										10 km.									
5—10	14	7						7	14	7	5	0							20	.
10—15									7	14								..		20
15—25									7	21									40	
25—40								7		7				.						20

AJMER

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	84	11	1				4	7	17	10	51	8	2					10	10	6
10—15			5					4	17	12		.	..	.			2	6	20	10
15—25			.	.				8	5	1				.				8	14	4
25—40	.	.																	2	.
	8 km.										10 km.									
5—10	12	0							17	8	6	0		.				.	.	17
10—15								8	8	25						..	.		33	17
15—25	.	.						8	25							.	.	..	17	17

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AGRA																				
	4 km.										**6 km.**									
5—10	388	7	2				1	6	11	7	312	3	1					1	5	5
10—15			1					8	21	15			2				1	2	22	12
15—25			1					2	9	7								6	26	5
25—40									1									1	5	2
40														.					1	
	8 km.										**10 km.**									
5—10	178	3	1						3	1	76	3							4	
10—15			1					1	13	7								1	7	7
15—25								3	27	11			1					1	26	7
25—40			1					4	17	5								4	26	5
40	..					.		1	3					.					7	1
ALLAHABAD.																				
	4 km.										**6 km**									
5—10	31	3							26	10	12	0							8	
10—15									26	13									25	.
15—25			..						13	10								8	33	17
25—40					..														.	8
	8 km.										**10 km.**									
5—10	2	0																		
10—15																				
15—25								50		50										
PATNA																				
	4 km.										**6 km.**									
5—10	42	10		2					12	5	18	0	6						11	11
10—15								2	14	12									17	28
15—25									26	17									17	6
25—40																			6	
	8 km.										**10 km**									
5—10	8	0							13		1	0								
10—15			13			.			13						.			.		..
15—25									37	25									100	
RANGPUR																				
	4 km										**6 km**									
5—10	15	7	7	.						20	6	0	17	.						17
10—15	.				7		.	7	27	7			17							17
15—25									7	13			..						17	.
25—40														.	17	.				
TEZPUR																				
	4 km										**6 km.**									
5—10	14	21			.				21		2	0						.	.	50
10—15								7	14					.						.
15—25									29				.			.	.	50		.
25—40		.	..	.	..	.	..	.	7		.	..	..		..			.		..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
CALCUTTA																				
	4 km.										6 km.									
5—10	175	6	3					1	10	12	111	6	2				1	2	7	4
10—15			1					1	18	27			2					3	19	16
15—25			1						9	11			1					2	29	7
25—40									1											
	8 km										10 km.									
5—10	24	4	4						4	8	4	0	25							25
10—15								4	13	13									50	
15—25								8	29	4										
25—40									4	4										
DACCA																				
	4 km										6 km.									
5—10	41	7							10	2	13	0								
10—15								2	34	12								8	38	8
15—25									17	10								8	38	
25—40									2	2										
CHITTAGONG																				
	4 km										6 km.									
5—10	29	10	3					3	17	31	8	0							13	13
10—15								3	14	17			13					13	13	13
15—25																		13	13	
	8 km										10 km.									
5—10	2	0																		
10—15																				
15—25									100											
AKYAB																				
	4 km										6 km									
5—10	241	26	8				2	3	12	17	131	8		1				3	15	11
10—15			3					1	7	14			2					7	20	11
15—25			1						1	3			1					4	15	2
25—40																			1	
	8 km										10 km									
5—10	39	0	3					3	3	3	11	9	9						9	
10—15								3	13	8								9		9
15—25			3					8	31	10							9		9	
25—40									13								9		18	9
MANDALAY.																				
	4 km.										6 km.									
5—10	44	14						2	25	14	9	0							11	
10—15									30	7									33	11
15—25								5		5									22	22

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
RANGOON																				
	4 km.										**6 km.**									
5—10	49	57		6			4	10	10	8	34	26	3				.	9	38	12
10—15									2	2									12	
	8 km.										**10 km.**									
5—10	6	17							33	17									.	.
10—15																		.		..
15—25								17	17											.
JUBBULPORE.																				
	4 km.										**6 km.**									
5—10	62	13	3				2	10	19	10	35	3	3			.		6	14	14
10—15						2		10	21	11			3	..				9	11	23
15—25			..																9	6
	8 km.										**10 km.**									
5—10	3	0		.					33	33	1	0	.							
10—15				.									.							
15—25									33										100	
RANCHI																				
	4 km.										**6 km.**									
5—10	36	11		.			..	3	8	8	13	8	8					8		23
10—15									44	14								8	15	15
15—25									11		..								15	
	8 km.										**10 km.**									
5—10	5	0									2	0								
10—15						.			20	20										
15—25									40	20										
25—40				.	.													50	50	.
SAMBALPUR.																				
	4 km.										**6 km.**									
5—10	29	17	7				3		21	24	21	19			.				10	24
10—15									17	7								10	29	10
15—25									3											
	8 km.										**10 km.**									
5—10	10	10	.						10	20	4	0								.
10—15								10	20			.							25	
15—25									20										25	..
25—40									10										50	

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
POONA																				
	4 km.										6 km									
5—10	202	45	.	1	4	4	12	13	3	1	172	21	4	6	2			4	16	10
10—15	..	..					3	6					3	1	1			3	9	4
15—25		..						1	1				2					3	9	1
25—40																		1	1	..
	8 km.										10 km.									
5—10	111	16	4	1			1	6	8	4	51	2						2	10	2
10—15			4	1				6	12	5								8	8	10
15—25			1				1	8	13	6								6	27	12
25—40								1	4	1			2					6	4	2
HYDERABAD.																				
	4 km.										6 km.									
5—10	51	55	4	18	2			2		4	39	33	5	3	3		5	5	21	8
10—15			6	10									3				.	5	8	3
	8 km.										10 km.									
5—10	31	6	3	3		6		6	10	3	8	13								
10—15			3					3	23	16								13		
15—25								3	10	3								13	25	13
25—40																			25	.
WALTAIR.																				
	4 km.										6 km.									
5—10	62	52	13	13	2	3	..		5	5	37	30	3		5			8	24	19
10—15				8														3	3	..
15—25																		.	.	5
	8 km.										10 km									
5—10	10	0	10					10	10		3	0								..
10—15								20	10	10								33		..
15—25				10					10	10								67		..
MANGALORE.																				
	4 km.										6 km.									
5—10	33	39		12	12	9					15	33		20				7	7	..
10—15				6	12									13	7					..
15—25				6	3									7						.
25—40														7				.	.	..
	8 km.										10 km.									
5—10	1	100									.		.	.	.	.		..	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in APRIL.

BANGALORE

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	310	26	2	19	12	5	1	1	2		190	50	2	4	9	8	1	2	5	3
10—15			1	17	7								2	2	3	2	1	2	2	1
15—25				6	1									1	1	1		1	2	
	8 km										10 km									
5—10	127	50	2	2	4	7	1	3	3	9	67	54	3	3	1	3	4	9	12	4
10—15			5	1	2	1	1	2	2	1					1		3	6	7	3
15—25			1	2				2	2									3		
25—40																			1	

MADRAS.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km									
5—10	148	37	7	22	8		1	1	2	1	110	51	3	8	11	6	5	2	2	4
10—15			5	7	5								3	3	3					
15—25			1	3	1										1		1			
	8 km										10 km									
5—10	48	48	2	6	2	2	2	2		6	15	60	7			7	7	7		7
10—15	.		4		2	2	2	6	2	4										
15—25						2				2			7							
25—40				2																

PORT BLAIR

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km									
5—10	152	64		6	11	4	2	3	3	1	126	42	5	8	15	6	3	2	4	5
10—15			1	1	4				1				2		2		2		2	2
15—25															1				1	
	8 km										10 km									
5—10	74	41	3	3	4	4	7	1	5	4	40	30	3	5	3	7		7	3	7
10—15			3	4	4	4		1	3	4			3	3	5		3	3	3	
15—25					3				1	1			5				3	5		3
25—40													3							

TRIVANDRUM.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	48	27	4	10	19	6		2	4	2	16	6	6	25	6	6			6	13
10—15			2	2	10			4							13	6			6	
15—25					2									6						
	8 km.										10 km.									
5—10	1	0			100	.				.										

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN.																				
	4 km.										**6 km.**									
5—10	35	17	3	23	6						20	40	5		15	.		.	..	..
10—15				40	3										20		.	.	..	..
15—25				9									.	20			.	.	..	..
	8 km										**10 km.**									
5—10	4	25			25				25		2	0					50	..	..	..
10—15					25													50	.	..
BAHREIN																				
	4 km										**6 km.**									
5—10	55	18	9		4	2	2		5	13	28	30	7				4	4	4	14
10—15			5		2	2		4	15	9			4					7	7	4
15—25									7	4			1						7	..
	8 km.										**10 km.**									
5—10	16	13						13	13	6	5	0								.
10—15							6	6	13	6									20	.
15—25			6						19									20	20	.
25—40																		20		20
MUSCAT.																				
	4 km.										**6 km**									
5—10	85	38	4	2	5	2	4		11	12	62	19	3				2	8	21	11
10—15			1		5				7	8				2			2	6	13	5
15—25									2									2	2	5
	8 km										**10 km**									
5—10	26	4						4	12	4	11	0								..
10—15									12	8								9		.
15—25							4	23	19									9	36	9
25—40									12									9	9	
>40																			9	9
GWADOR																				
	4 km										**6 km.**									
5—10	54	41	7	9	4	2	2	6	15	4	15	13						4	18	9
10—15			4		2				4	2			2		2			9	16	11
15—25													2					2	4	4
25—40																		2		
	8 km										**10 km**									
5—10	13	15	8						8		3	0								.
10—15								23	23										100	
15—25								8	15											
KARACHI.																				
	4 km.										**6 km.**									
5—10	93	39	14	6	4			1	4	12	60	16	4	3				1	10	19
10—15			1				1	1	5	6			1				3	3	14	4
15—25									2	2			1					4	10	4
	8 km.										**10 km.**									
5—10	37	11						5	8	8	10	10					.	10	10	
10—15									14	11									20	10
15—25									32	5									40	
25—40								3	3											.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
QUETTA.																				
	4 km.										6 km.									
5—10	237	17	3					3	12	16	103	25	8	2		1		4	3	12
10—15	.								7	22			3					2	8	13
15—25									5	15			1				2		6	9
25—40										1									1	1
>40																				1
	8 km.										10 km.									
5—10	53	11	6	2	2	2		2	9	9	20	10	10		5			5	10	10
10—15			6					2	9	9			5						5	15
15—25								2	9	13								5	15	5
25—40	.							2		4										
PESHAWAR																				
	4 km.										6 km.									
5—10	212	24	5	2	1	1	3	8	23	13	181	13	4	2	1		1	5	12	12
10—15			1				1	4	7	6			1	1	1		1	5	19	7
15—25									1				1					2	9	4
	8 km.										10 km.									
5—10	102	14	2	1	1			4	8	8	61	2	3	2				2	7	
10—15			2					4	15	8								5	10	13
15—25			4					2	21	5			3	2				10	18	11
25—40									1	2									8	2
LAHORE.																				
	4 km.										6 km.									
5—10	334	19	7	1		1	2	5	10	15	247	9	4			2	1	3	10	13
10—15			2				1	4	8	16								3	13	19
15—25						1	1	1	2	4								3	10	8
	8 km.										10 km.									
5—10	158	6	2	1				2	8	5	74	5	1		1			1	4	3
10—15			3					1	15	10							1	4	8	8
15—25					1	1	1	2	25	10					1		1	5	19	15
25—40									6	1								1	14	4
>40	.								1										1	
SIMLA.																				
	4 km.										6 km.									
5—10	404	32	3	1	1	5	3	2	6	20	267	15	4	1	2	1	3	7	14	9
10—15						3			1	15			1		1		2	5	12	11
15—25	.					2		1		3							1	3	3	5
	8 km.										10 km.									
5—10	182	11	3	1	1	1	1	3	8	4	97	11	2					2	6	2
10—15		.			1	1	1	2	13	8				1				5	8	3
15—25	.		1	1		1		10	19	5			3					3	18	7
25—40								2	4	2			1					7	14	2
>40								..		.	.	.	.					1	2	

n represents the total no. of observations,
C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

DELHI.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
4 km.										
5—10	27	19	7						7	15
10—15									7	22
15—25										22
6 km.										
5—10	12	25	8						25	8
10—15									8	8
15—25										17
8 km.										
5—10	5	0								20
10—15									20	40
15—25									20	
10 km.										
5—10	2	0								
10—15									50	
15—25										50

AHMEDABAD.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
4 km.										
5—10	70	44	6			1		6	11	11
10—15								9	4	1
15—25								4	1	
6 km.										
5—10	53	28	6		2			2	13	15
10—15			8	2				6	13	2
15—25										4
8 km.										
5—10	21	10			5				14	19
10—15			5					5	14	10
15—25									10	5
25—40									5	
10 km.										
5—10	9	0		11					11	
10—15									11	11
15—25									55	
25—40										

AJMER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
4 km.										
5—10	86	29	8	3		1	1	3	5	12
10—15			6					3	7	6
15—25			1					1	8	5
25—40										
6 km.										
5—10	54	7	9	4				4	4	7
10—15			6	2				4	15	13
15—25			2						9	7
25—40			2					2	4	
8 km.										
5—10	10	0					10		10	10
10—15	.		.						10	
15—25									20	30
25—40										10
10 km										
5—10	5	0								.
10—15									20	
15—25										40
25—40									20	20

AGRA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW
4 km.										
5—10	330	16	2	1	.	1	2	6	16	16
10—15	.		1				1	4	11	14
15—25								2	2	5
25—40		.	.	.						
6 km.										
5—10	233	10	3			1	1	3	11	10
10—15			1					6	18	11
15—25			1			2		4	10	6
25—40									1	1
8 km.										
5—10	145	13	1	.	1		3	1	5	6
10—15	.		2				1	3	9	8
15—25		.					1	9	17	6
25—40		.						1	6	2
>40	..	.	.					.		1
10 km.										
5—10	67	18	3				3	4	6	6
10—15				1					13	1
15—25			.					7	16	7
25—40	.						.	4	3	3
>40		.				.	.	1	.	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

ALLAHABAD

4 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	33	6	3	3					18	9
10—15					3			6	18	18
15—25									3	9
25—40										3

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	11	27							27	
10—15										18
15—25									9	18
25—40										

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	6	17								17
10—15									33	
15—25										17
25—40										17

10 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	2	0								50
10—15										
15—25			50							
25—40										

PATNA.

4 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	58	7	2	2	5			2	5	16
10—15			2		2			2	10	16
15—25			2						9	17
25—40										3

6 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	31	13	10	3				3	6	10
10—15						3			10	19
15—25								3	6	10
25—40										3

8 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	16	19								13
10—15								13		13
15—25			6					6	19	6
25—40										6

10 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	5	0						..	40	
10—15			20							20
15—25										
25—40								20		

RANGPUR.

4 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	19	37			11				5	5
10—15					11				11	5
15—25									11	5

6 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	10	0			20			10	20	10
10—15									10	
15—25										10

8 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	4	0	25						25	
10—15								25	25	
15—25										
25—40										

10 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	3	0							33	..
10—15										
15—25									33	
25—40								33		

TEZPUR.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	12	75						8	8	
10—15					8					

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	8	37							37	.
10—15								13	13	..

8 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	2	0								
10—15								50		50

10 km

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10									..	..
10—15									..	.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	SE	SE	S	SW	W	NW
CALCUTTA.																				
	4 km										6 km.									
5—10	172	13	10	2			1	1	9	12	96	33	3		2			4	15	6
10—15			5					1	5	26			3		1			4	11	6
15-25			1						1	13								1	4	5
	8 km										10 km									
5—10	44	30	2	5			5	9	9	2	18	11							28	22
10—15								7	11	2				6			6		11	11
15—25			2		2				14										6	
DACCA																				
	4 km										6 km.									
5—10	28	30	4			7	4		4	14	14	29	7	14		7			29	
10—15										14								7		
15—25									7	11										7
	8 km										10 km									
5—10	4	75							25		1	0							100	
CHITTAGONG																				
	4 km										6 km									
5—10	31	32						3	13	16	12	58							8	17
10—15			3						10	19							8			8
15—25			3																	
	8 km										10 km.									
5—10	5	20		20		20			20	20	2	50				50				
AKYAB.																				
	4 km										6 km									
5—10	216	39	4		3			5	8	17	112	29	4	2	2		1	4	16	10
10—15			6					2	3	8								5	18	5
15—25									2	2			2				1	1	1	1
	8 km										10 km									
5—10	45	29	2				2	2	9	2	20	30					10	10	15	5
10—15			4					7	11	2								5	5	
15—25			2					4	16	4				5				10		
25—40									2											5
MANDALAY																				
	4 km										6 km									
5—10	55	36						9	18	9	23	65							17	4
10—15				.					15	11										9
15—25				.						2								4		
	8 km.										10 km.									
5—10	8	75			..			13		13									.	..

n represents the total no of observations,
and C represents percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
						RANGOON.														
					4 km.										6 km.					
5—10	35	69	9	9			3	9	3		13	31		8	..		8	8	15	8
10—15															..			..	..	.
15—25														15	..			8	..	
					8 km.										10 km.					
5—10	3	33							33								..	.	.	
10—15															..		.	..	.	
15—25				33											..	.		..	.	
						JUBBULPORE.														
					4 km										6 km.					
5—10	60	12	8				2	7	23	20	30	13	3					10	17	10
10—15								7	10	8			7					3	10	17
15—25									3				3	.			.	..	3	3
					8 km										10 km.					
5—10	8	0							25		1	0					.			.
10—15									25									100	..	
15—25				.				.	37	13				..		.			..	
						RANCHI.														
					4 km.										6 km.					
5—10	38	8	5	3		3			3	11	21	10	5				.	.	14	5
10—15			3						26	13								5	5	10
15—25									5	16						..	..		19	24
25—40																	..		.	.
>40										3							.		.	..
					8 km.										10 km.					
5—10	4	0								25	3	0		.			.			33
10—15																				
15—25								25	25									.	33	33
25—40	.									25										..
						SAMBALPUR.														
					4 km.										6 km.					
5—10	24	21	4						4	25	15	53	13				..	..		
10—15			8						8	17			7		..		.	..	.	
15—25									4	8			.				.	..	7	
					8 km										10 km.					
5—10	7	43		.	.	.					2	0	.	..	50	..	..	..	..	..
10—15					.				14	14		.	..	.	.	.	..	50	..	..
15—25		.									.		.		.	..	..	..	..	..
25—40		.			.				14	14				.	.	..	.	.	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
POONA.																				
	4 km.										6 km.									
5—10	193	51	1	2	6	5	12	8	4	2	151	40	12	5	1	.	1	3	6	11
10—15			1	2	1		2	4	2	1			4	5	1		.	1	3	6
15—25	..			1									1	.			..	1	..	1
	8 km										10 km.									
5—10	102	34	5	2	4		2	1	7	9	50	36		6		4	4	4	10	6
10—15			6					2	6	7			4				..	2	4	8
15—25			1					4	5	6					.		.	2	4	6
HYDERABAD.																				
	4 km.										6 km.									
5—10	54	30		24	11		2	4		4	35	34	17	3		3	.	.	9	3
10—15		..	2	13	2				2	2			6	14	3			.	3	6
15—25	.		2	4		.											..			..
	8 km.										10 km.									
5—10	20	20	15	15				10	10		11	18	9					9	9	9
10—15			5	5		.		10	5	5								9	18	..
15—25									..				9						9	..
WALTAIR.																				
	4 km.										6 km.									
5—10	51	37	18	16		2	2	2		6	23	22	13	17		.		4	9	17
10—15			8	4			.			4				9	..	.		.	4	..
15—25										2		..	4	.	..	.	..	.	.	..
	8 km.										10 km.									
5—10	8	25	37	13							1	0					.	.	100	..
10—15									13	.						.	.	.		.
15—25													.							..
25—40			..	13													.		.	..
MANGALORE.																				
	4 km.										6 km.									
5—10	30	30			20	3		3	3		14	43		7	21	7	7	.	.	..
10—15	.			3	27								.	14				.	.	..
15—25	.				10		.	.									.	..	.	..
	8 km.										10 km.									
5—10	2	0		100					.				.	..				..	..	..
BANGALORE.																				
	4 km.										6 km.									
5—10	291	29	1	19	15	2	2	1	1	2	187	57	6	7	11	2	1	3	1	6
10—15	.			16	7									2	3			1		1
15—25		.		3	1									1						..
25—40		.			.													.	1	..
	8 km.										10 km.									
5—10	114	52	6	9	8	1	1	5	5	3	57	44	5	5	12	5	..	5	9	..
10—15	.	.	3	.	3	.	.	1	1	3			2	..	5	2	..	..	..	..
15—25	..	..	..	..			.		.	.	.		.	.	..	..	..	2	3	..

n represents the toltal No of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in MAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
MADRAS.																				
	4 km.										**6 km.**									
5—10	157	25	7	21	5	1	1	1	1	3	102	48	6	5	9	2		4	6	4
10—15			4	23	3				1				1	5	5			1	1	.
15—25	.		1	3	1									2	1					.
25—40															1					..
	8 km.										**10 km.**									
5—10	63	38	11	13	8	5	2	5		2	39	23	5	23	21	3	3	3		.
10—15			3	3	3					3				3					3	8
15—25				2	3							.	3						3	3
PORT BLAIR.																				
	4 km										**6 km.**									
5—10	88	60	6		8	.	3	o	5	1	56	55		.	5	4	11	4	9	7
10—15					1			1	3						2	2				..
15—25							1			1	.	.						.	.	
	8 km.										**10 km.**									
5—10	26	54	8				4		19	4	16	37		.	6	6		6	6	6
10—15	.							4	4									6	25	.
15—25					4															..
TRIVANDRUM.																				
	4 km.										**6 km.**									
5—10	30	10	10	7	7				17	10	8	0	25		13	13		.		13
10—15			3		3	3	3		10	10							.		13	13
15—25					3				3						13		.			..
	8 km.										**10 km.**									
5—10	1	100	..			.					1	100			.					.

n represents the total No of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JUNE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN.																				
	4 km.										6 km.									
5—10	47	28	4	23	4		.	.	..	4	25	4	.	12	8			..	.	..
10—15			6	23	2								8	48			..	.	.	.
15—25			2	2										20		.	..			.
	8 km.										10 km.									
5—10	8	13		25	25	13	.	.			4	0		25				.	..	..
10—15			.	25		.	.							25	50		.	.	..	..
BAHREIN.																				
	4 km.										6 km.									
5—10	39	23	15	10	3	3	3		5	8	20	30	5	15	5	5		5	10	5
10—15			5			5	.		3	8					10			5	..	.
15—25				3	3		.			5			5		..	.	.		..	..
	8 km.										10 km.									
5—10	12	0		8	8			17	25	17	7	14		14		14			14	
10—15	.			8	8			8											28	..
15—25							..										.	14	..	..
MUSCAT.																				
	4 km.										6 km.									
5—10	79	30	4	20	14	6	1	3		1	44	25	16	11	5	.		..	2	9
10—15			3	4	9			1		3			7	14	2		.	..	..	2
15—25										1			2	2	.		.	..	..	2
	8 km.										10 km.									
5—10	16	31	19	6		6		6	6		8	87	13		.		.	..	..	..
10—15	.	.		6	12	.		.		6							..	..	..	..
GWADOR.																				
	4 km.										6 km.									
5—10	38	26	11	8	11	3	.			11	17	29	6	6					.	18
10—15		..	8	16	3	..				3				12	.			.	12	..
15—25					3	..	.				.			6	6	6	.		.	..
	8 km.										10 km.									
5—10	4	25	25	..		.	.	..	25	.	2	100	.		.		.	.	..	..
10—15	..	.		25	.								..	.	..	.	..	.	..	..
KARACHI.																				
	4 km										6 km.									
5—10	66	35	11	15	5	..		5	1	6	47	28	4	2	..	2	.	15	9	2
10—15	..	..	1	14	..	..	.	.		.	.	.	2	2	6		2	6	2	4
15—25	..	.	1	5	..	..	..	..	..	..	..	..	..	13	.	..	..	..	..	..
25—40	.	..	..	1	..	..	..	..	..	..	.	..	..	.	.	.	.	..	..	..
	8 km.										10 km.									
5—10	24	13	8	.			4	13	21	8	12	25	8				.	8	17	8
10—15	..	.	..	4	4	..		8	4								..	8	..	8
15—25	..	.	..	..	..	.	.	4	8					.		.	..	..	17	..

n represents the total No of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JUNE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
QUETTA.																				
	4 km.										**6 km.**									
5—10	271	31	7	1				4	10	22	143	28	3	2	3	1	3	2	8	18
10—15	..		1	.					5	10			6	2		.	.	1	3	10
15—25	.		1	..				.	1	4			2		.			.	3	5
25—40		.	.	.			.			1								.		1
	8 km.										**10 km.**									
5—10	62	5	.	3					11	6	18	6		6			.	..		6
10—15	.	.	6	2				5	10	15					.			..	11	11
15—25	..			.				3	23	8							.	.	17	6
25—40	.								3					.			.	.	39	..
PESHAWAR.																				
	4 km.										**6 km.**									
5—10	210	38	5			.		9	20	20	165	21	7		1	.	.	3	17	14
10—15	..	.	1		.	.	1	1	2	1			3	1		.	..	1	12	9
15—25	.		..		.	..							1		.			1	8	1
25—40	.	.	..	.	..	.					.						.	.	..	1
	8 km.										**10 km.**									
5—10	69	19	3			1		7	13	6	30	3							7	7
10—15	..	..	1	3					13	12	..							3	10	13
15—25	.	.	3					.	7	9	.							10	27	7
25—40	..		.	.					1	1						.			10	
40				.										.				.		3
LAHORE																				
	4 km.										**6 km.**									
5—10	245	32	9	2				1	9	28	162	27	9		1		1	2	14	12
10—15			6						3	7			2	1				2	6	18
15—25										1			1	.					2	2
	8 km.										**10 km.**									
5—10	112	11			2		..	1	8	8	51	6		.	.	2	2	.	4	2
10—15		.	1		.		1	6	16	7		.	.	.			.		10	6
15—25	..	..	..	1	..	.	.	13	19	4				.		.		8	27	10
25—40								1	2	1			2					6	14	2
SIMLA.																				
	4 km.										**6 km.**									
5—10	314	45	3		.	5	2	1	3	21	202	39		1	.	1	4	9	14	12
10—15		.	.			2		.	1	16					.	1		3	4	6
15—25	.	.	.		.					1			.	.	.	.		.	1	7
	8 km.										**10 km.**									
5—10	135	11	1		1	1	.	3	7	7	57	7	.	2	4	2		5	4	5
10—15	.	.	.	.	1	.	1	7	15	5	.			.		2		5	4	5
15—25	..	..	1	.	2	1	1	10	14	5	.				2		5	7	18	11
25—40		..	.				.	1	1	1						.		7	7	.
DELHI.																				
	4 km.										**6 km.**									
5—10	17	38	24	..	12	.				12	8	25	25	.			..	.		..
10—15	..	..	12	..	..	.	.	.		.	.		13	..		..	.	..	13	.
15—25	..	..	6	..	..	..	..	.		.	..	.		..	.	..	.	..	13	13
	8 km.										**10 km.**									
5—10	3	0	..	..	..	.	.	.				.	..	..	..	.		.		..
10—15	..	..		..	.	.		.		33	.	.	..		.			.	..	.
15—25	..	.	.	.	..	.	.	.	33			.		.	.		.	.	.	.
25—40	..	..	.	.	..	.	.	.	..	33	...	..		..	.	..	..	.	..	..

n represents the total no of observations,
and C represents the percentege number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JUNE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AHMEDABAD.																				
	4 km.										**6 km.**									
5—10	63	46	5	11	3	5	3	2	2	3	40	47	3	3	3	3	3	5	10	15
10—15	..		.	8	3	2	2	..	2					3	3			.	3	.
15—25				5										3					..	..
	8 km.										**10 km.**									
5—10	20	45	5		5			15	10	5	12	25	8			8		8	.	8
10—15	..		.						10	5			8			8		8	..	..
15—25																	.	8	.	..
AJMER.																				
	4 km.										**6 km.**									
5—10	95	33	13	4	2	1	2	5	6	7	64	22	12	5	2	2	2	2	8	9
10—15			6	4	1			2	5	1			12	3				3		5
15—25			2						1					3				2	5	5
	8 km.										**10 km.**									
5—10	17	18		6						6	7	57		..				.	.	..
10—15	..	.				.		.	6	6			.	..	..				..	..
15—25		.	18				6		23	12									14	..
25—40			.	.									14			.			..	..
40				.													14		..	..
AGRA																				
	4 km										**6 km**									
5—10	291	28	12	3	2		1	3	8	13	211	33	5		4	1	3	6	13	10
10—15			7	1				1	4	12			1		1			3	8	5
15—25									1	3								1	3	1
25—40																	..	.		..
	8 km										**10 km.**									
5—10	140	33	4		4	3	2	5	9	6	96	39	3	2	4	3	2	5	8	1
10—15			1	1		1	1	2	6	4			3		3	2	2	3	6	5
15—25			1					6	9	1								2	3	..
25—40									1	1								2	.	..
ALLAHABAD.																				
	4 km										**6 km.**									
5—10	24	17		8	4				8	21	12	8		17				8	8	..
10—15					8				17	17					8			17	8	17
15—25															8			.		
	8 km.										**10 km.**									
5—10	8	13	25								5	40						.		.
10—15				13	13				25				20						20	20
15—25										13							.	.		..
PATNA.																				
	4 km										**6 km.**									
5—10	61	38			7	5	3	7	11	7	37	41	3		8	8		3	14	5
10—15					5			2	2	8					3			8	8	..
15—25									3	3							..		.	..
	8 km.										**10 km.**									
5—10	19	21	..			5	11	5	21		12	25					17	8	.	8
10—15	..	..	..	.	.	.		21	5	5					.	.	..	8	33	..
15—25		..	..	.					5						.		.	.	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JUNE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
RANGPUR.																				
	4 km.										6 km.									
5—10	7	71									1	0	..	100	.	..		.	.	..
10—15					14											..			.	..
15—25					14										.	..	.	.		
TEZPUR.																				
	4 km.										6 km									
5—10	10	30			10			10	20		2	50								..
10—15	.				10				10	.				..			..	50		..
15—25	.				10									.		.		.	.	..
CALCUTTA.																				
	4 km.										6 km.									
5—10	111	42	8		2	2	2	5	4	7	56	57		4	11	7	2	4		5
10—15			5		1				4	13	.			2	2	..	2		2	..
15—25	.				2					5			.			.	.	2	2	..
	8 km										10 km.									
5—10	20	55	5	5	15	5	5		5		12	25		8	25	17	8		8	
10—15								5									.			.
15—25												.					8		.	
DACCA.																				
	4 km.										6 km.									
5—10	22	41			5	14	5	5		14	7	71		..	.	29		.	..	
10—15					9	9								.			.	.	..	..
	8 km.										10 km.									
5—10	1	0					100				.					.	.			..
CHITTAGONG.																				
	4 km.										6 km.									
5—10	9	67				11		22		..	2	0	.	..	..	50	50	.		.
AKYAB																				
	4 km.										6 km.									
5—10	57	53	2	5	2	7	11	5	7	5	1	34	3	..	19	19	6	3	..	3
10—15	.	..	.	.		..			2	2	.	..	..	.		10	..	.	..	..
	8 km.										10 km.									
5—10	11	36	9	.	27	9	9	.	.	..	9	33	.	11	11	.	..	..	..	..
10—15	..	..	.	..	..	9				..	..	..	.	..	33	11	..	..	..	..
MANDALAY.																				
	4 km.										6 km.									
5—10	42	52	..	..	..	7	2	12	12	12	24	67	..	..	..	13	4	4	8	..
10—15	..	..	..	..	..	.	..	..		2	..	..	..	.	..	..	..	..	4	..
	8 km.										10 km.									
5—10	3	33	..	.	..	33	.		33	..	.	.	.	..	..	.	..	..	..	.

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8, and 10 km. in JUNE.

RANGOON.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	9	66	.	.			11		11	11	1	100	.					.	.	..

JUBBULPORE.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	45	40	18		7		2		4	16	20	55			.			5	10	5
10—15			2	2	4				2						5				20	..
15—25										2									.	..
	8 km.										10 km.									
5—10	8	37			13	13		13		13	6	50	17			17		17	..	
10—15										13									.	.

RANCHI.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	33	48					3	3	3	12	15	53	7			..	7	13	7	..
10—15								3	3	15									.	..
15—25									3	6									7	.
25—40																..	.		..	7
	8 km.										10 km.									
5—10	6	17			17			33	33		2	0		.	.	.		..	100	..

SAMBALPUR.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	31	35	13	10		..		10	3	10	16	50	6		6	6	6		6	13
10—15			3				.		6	10			6					..		..
	8 km.										10 km.									
5—10	3	33				33					1	100							..	..
10—15			33															.	..	

POONA.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	90	55	8	8	4	4	3		7	2	49	59	2	8		6	6	2	4	..
10—15	.		1		3	2	2						4	4					..	..
15—25													2	2			.	.	..	..
	8 km.										10 km.									
5—10	24	71	8	13	4						13	46		8	8	23		..	..	..
10—15		.	4		.											15	.		.	..

HYDERABAD.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	38	55	3	5	8	.	8	3	13	3	20	65		10	5	5	5	5	5	..
10—15	..		3												.		..	..	..	..
	8 km.										10 km.									
5—10	10	80	..	20	..	..	.	.	..		5	0	..	80		..	..	..	..	..
10—15	..	..	..	..		..	..	.	.	..		..	.		20	..	..	..	..	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JUNE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
WALTAIR.																				
	4 km.										**6 km.**									
5—10	37	49	16	8	3	5	3		8	3	13	46			38		8			8
10—15								3		3										..
15—25																			8	..
	8 km.										**10 km.**									
5—10	3	67			33						1	0				100		..	.	..
MANGALORE.																				
	4 km.										**6 km.**									
5—10	3	100									1	100					.			..
	8 km.										**10 km.**									
5—10	1	0	100			..					1	0			100				..	
BANGALORE.																				
	4 km.										**6 km.**									
5—10	94	64			9	2	3	4	6	5	56	68		5	5	5	2	4	7	..
10—15					2				2	1									4	
15—25				1																.
	8 km.										**10 km.**									
5—10	21	48		5	24	14	5				8	25		13	50	13				
10—15																				
15—25					5															
MADRAS.																				
	4 km.										**6 km.**									
5—10	124	48	1	4	3	2		6	17	6	60	60		3	5	2	2	10	8	2
10—15									9	1				3				2	2	
15—25									3	1									2	..
	8 km.										**10 km.**									
5—10	31	55	3	10	10	3			6		19	26		5	37					..
10—15				6	6	3								5	21	5				..
PORT BLAIR.																				
	4 km.										**6 km.**									
5—10	34	47				3	6	9	9	6	18	67				6	6	11		.
10—15							6	3	9				6						.	.
15—25									3								.	6	..	.
	8 km.										**10 km.**									
5—10	8	25	13	13	50						4	0			25		25		..	..
10—15															25			.	..	..
15—25															25	.			..	..
TRIVANDRUM.																				
	4 km.										**6 km.**									
5—10	10	40	.	10	..	..	..	..	20	20	4	0	25	.	25	.		..	..	25
10—15	..	..		.	.		.	.	10			.	.	..		.	..	..	..	25

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JULY.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN.																				
	4 km.										**6 km.**									
5—10	39	38	13	23	8					5	27	0	4	11		.		..	.	.
10—15				8	3				3				7	30	11			.	..	..
15—25											.		4	30					.	..
25—40														4		.			.	..
	8 km.										**10 km.**									
5—10	4	0		50							3	0		67			.			..
10—15				50										33			.	.	..	..
BAHREIN.																				
	4 km.										**6 km.**									
5—10	34	47	12		6	3			6	6	14	43	7	14	7	7			..	..
10—15			6		3	3				3				7					..	7
15—25	.		.	3						3					.				.	7
	8 km.										**10 km.**									
5—10	6	67									4	50				25				..
10—15			17	17											25				..	..
MUSCAT																				
	4 km										**6 km.**									
5—10	72	40	7	10	10	3			1	6	31	32	3	19	16	6		..	..	..
10—15			6	12	1	1			1				3	6	13				.	.
15—25	.				1											..		..		..
	8 km.										**10 km**									
5—10	5	0		40	40						3	0			100					..
10—15					20														..	..
GWADOR.																				
	4 km.										**6 km**									
5—10	25	44	20							20	8	37	13	13	13				..	..
10—15			8	4						4				13	13					..
	8 km.										**10 km**									
5 –10	1	0		100							1	0		100					.	..
KARACHI.																				
	4 km.										**6 km.**									
5—10	38	8	8	14	8						14	29			7	14	.		..	..
10—15			5	32	8								7	21			.	..	..	..
15—25			5	5	8									7	7				..	..
25—40														7				.	..	..
	8 km.										**10 km.**									
5—10	4	25			25						1	100				.		..	..	:
10—15			.	25						..						.		..	..	..
15—25										..							.	..	..	..
25—40		.		25										.	.	.	..	..	..	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JULY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
QUETTA																				
	4 km.										**6 km**									
5—10	276	36	9	4	1		1	3	13	16	142	35	9	6	6	4	5	4	8	7
10—15			1						7	6			1	5	1		1	1	1	3
15—25															1		1			2
	8 km.										**10 km.**									
5—10	76	29	5	4	3		3	4	9	12	46	22	7	7	4	2	2		11	9
10—15			6	3	3	1			5	5			7	2	4		2		2	9
15—25		.	4						1	3				2					4	4
PESHAWAR.																				
	4 km.										**6 km**									
5—10	215	43	11	2	.			2	10	26	172	36	6	3	1	1	1	4	12	13
10—15		.	1						1	3			2	1			1	1	6	7
15—25													2	1					1	2
25—40																				1
	8 km.										**10 km**									
5—10	79	25	4	1	1	3	3	8	6	3	32	16	3			3		6	28	3
10—15	.		3					3	9	4							13	3		3
15—25								3	6	14									13	
25—40	.		5							1			..						6	3
LAHORE.																				
	4 km.										**6 km**									
5—10	248	44	23	3	2	2	1	1	2	15	157	43	8	1	2	4	3	7	10	9
10—15			4					1	1	1			1	2				3	2	3
15—25													1							
	8 km.										**10 km.**									
5—10	114	25	4	2	2	4	2	9	9	8	69	17	3	1	1	3	4	9	6	2
10—15			2	.		1	2	7	7	7			1	1	1	3		12	12	3
15—25		.	1					4	4	3								3	3	3
25—40		.		.															1	..
SIMLA																				
	4 km.										**6 km.**									
5—10	188	66	1	.	1	6	1	1	1	15	102	48	3	1	6	4	9	16	5	4
10—15	..	..		.	.	2			1	6									1	3
15—25	.				..					2										1
	8 km.										**10 km.**									
5—10	67	33			3			10	6	3	37	16	3				5	11	14	3
10—15	..			1	1	3	1	13	9	1				3	3	..	.	14	3	..
15—25		.		..			1	1	6	4						.		16	11	.

n represents the total no of observations,
and C represent the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JULY.

DELHI.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	16	63	6		13	6		.			7	43	.				14	.	14	..
10—15									6						29				.	..
15—25									6					.				.		..
	8 km.										10 km.									
5—10	3	33						33												..
10—15																.	.	.		..
15—25								33												.

AHMEDABAD

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	17	71	..	6	12	12					5	80			20					
	8 km.										10 km									
5—10	3	33	..	..	67						1	100								..

AJMER

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	58	43	14	17	5	2	2	2	3	2	32	41	6	12	3	3			3	.
10—15	.	..	2	3	2									6	6	3			6	..
15—25				2	2									3	3			.		3
	8 km.										10 km.									
5—10	7	43									2	0	50							..
10—15				14					14											.
15—25					29														50	.

AGRA.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	225	48	8	4	13	3	..	1	3	6	151	52	2	3	11	7	4	5	3	3
10—15			2	1	3	1				4			1		4	3			1	1
15—25						1										1			1	.
	8 km.										10 km									
5—10	100	45	1	4	18	7	2	3	6	2	66	29	1	1	18	3	3	5	12	1
10—15					4	5							1	3	8	9			1	
15—25					2	1										1				.
25—40															1					.

ALLAHABAD.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	10	40				20				20	5	60			20				..	..
10—15																		..	..	..
15—25			10		10	.									20				..	..
	8 km.										10 km.									
5—10	1	100	.				.	..			1	100	.	.					.	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JULY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
PATNA.																				
	4 km.										6 km.									
5—10	40	43		5	10	7	.		3	10	21	33		5	23	14			.	
10—15				3	7	3				3					5					5
15—25	.				5									5	5	5			.	
25—40					3														.	.
	8 km.										10 km.									
5—10	7	14			43	14					3	0		33	67			.	.	..
10—15					14														.	.
15—25						14													..	.
RANGPUR.																				
	4 km.										6 km.									
5—10	7	43			14	14					4	50				25			..	
10—15					14												25			.
15—25					14		.													
TEZPUR.																				
	4 km.										6 km.									
5—10	21	57			19	10		10			8	37		13	13	13		13	..	.
10—15									5						13				..	.
	8 km										10 km.									
5—10	4	50			25						2	50							.	50
10—25					25													.		
CALCUTTA.																				
	4 km.										6 km.									
5—10	78	53			8	9	9	8	4	4	43	56	2	2	7	16	2	2	2	2
10—15					3			1	1		..				5		2		.	
15—25					1															
	8 km.										10 km.									
5—10	13	23			38	23	.		.		4	0				25		.	..	.
10—15			.	.	8	8									25			.	..	.
15—25		.		.						.	.				50	.	.	..	.	..
DACCA.																				
	4 km.										6 km.									
5—10	7	29			14	14			.		2	50				.	.	..	..	..
10—15	.				29											..		..	..	..
15—25					14		.	.				..			50				..	..
	8 km.										10 km.									
5—10	1	100		.	.	.		.		..	.	.	..	.		..	..	..	..	..
CHITTAGONG.																				
	4 km.										6 km.									
5—10	7	29	..	..	43	29	..	..	..	..	1	0		..	..	100	..	..	..	..

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PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JULY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AKYAB.																				
	6 km.										**6 km.**									
5—10	39	59			8	3	10	8	5	3	18	33		6	22	33	6	.		..
10—15	.								5					.	.	.		.	.	.
	8 km										**10 km.**									
5—10	5	20			60						2	0								..
10—15							20								50	50				
MANDALAY.																				
	4 km.										**6 km**									
5—10	26	54				12		4	12	8	9	78					22			
10—15						4		4	4									.	.	
RANGOON.																				
	4 km.										**6 km**									
5—10	7	57						14	14		1	0					100			.
10—15									14										..	
JUBBULPORE.																				
	4 km.										**6 km**									
5—10	7	86								14	1	100							..	..
RANCHI.																				
	4 km.										**6 km**									
5—10	5	80		20							4	50			25				.	..
10—15														25						.
SAMBALPUR.																				
	4 km.										**6 km.**									
5—10	7	43	14			14			14		4	75			25					.
10—15																				.
15—25	.								14											..
	8 km.										**10 km.**									
5—10	2	50			50															..
POONA.																				
	4 km.										**6 km.**									
5—10	8	75	..	.		13			13		3	67			.	33		..	.	.
	8 km.										**10 km.**									
5—10	3	33	..		33	33					3	0			33					
10—15	.						.								33					
15—25	.		..												33					.
HYDERABAD.																				
	4 km.										**6 km.**									
5—10	16	13	.	.				6	19	25	3	33						33	.	.
10—15	..		.						19	6									33	.
15—25	..	..	.						13			.				..	.	..	..	..

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and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in JULY.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
WALTAIR.																				
4 km											6 km									
5—10	16	19	6					6	13	13	2	50	50							
10—15								6	19	6										
15—25									13											
8 km											10 km									
5—10	1	0			100						1	0								
10—15															100					
MANGALORE																				
4 km											6 km									
5—10	2	50						50												
BANGALORE.																				
4 km											6 km									
5—10	31	71			3				10	13	17	71			12	12		6	.	
10—15									3											.
8 km											10 km									
5—10	8	37			50	13					4	25								
10—15															50					.
15—25															25					
MADRAS.																				
4 km											6 km									
5—10	107	21			2	1	1	9	21	3	49	26		2	4		2	12	16	2
10—15									30	4					4				4	
15—25								1	6	1									2	
8 km											10 km									
5—10	20	40	5	5	20	15				5	8	0		13	13					
10—15					10										63					
15—25															13					
PORT BLAIR																				
4 km											6 km									
5—10	35	37			3	3	23	9	9	6	20	55		5	10	20	5			..
10—15								6	6							5				
8 km.											10 km									
5—10	7	29			43	14	14				4	0			25					
10—15														50						
15—25														25						
TRIVANDRUM.																				
4 km											6 km.									
5—10	11	18	9	9							1	100								
10—15			9						27											
15—25										27										
8 km.											10 km									
5—10	1	0	100		.								.							..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in AUGUST.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	C	SW	W	NW
ADEN.																				
	4 km										**6 km**									
5—10	41	46	5	19	5						29	14	3	24	7	3				.
10—15			2	17	2				12					41	3					
15—25														3				.		
	8 km										**10 km.**									
5—10	6	17		33	33			17			1	0								
10—15																		100		
BAHREIN																				
	4 km										**6 km**									
5—10	66	38	8	12	6	9	3		2	6	50	32	8	10	10	6	2	4	2	8
10—15			2	2	6				2	5			4		6	4			2	2
15—25										2										
25—40										2										
	8 km										**10 km**									
5—10	25	44	8	8	12				12	4	9	33		22			11	11		
10—15			4		8										11				11	
MUSCAT																				
	4 km										**6 km.**									
5—10	96	48	8	8	5	2	1		2	10	51	45	4	8	8	4		8	6	2
10—15			2	6	4				1				2	6	4			2		
15—25					1									2						
	8 km										**10 km**									
5—10	11	7		9	9	9					6	33		17	17	17				
10—15															17					..
GWADOR																				
	4 km										**6 km.**									
5—10	11	45	18	6						9	1	100								..
10—15				9					9										.	..
	8 km.										**10 km.**									
5—10	1	100									1	100							..	..
KARACHI																				
	4 km										**6 km**									
5—10	27	11	15	11							13	23		15	8					8
10—15				22	7									15						..
15—25			7	26									8	15	8					..
	8 km										**10 km**									
5—10	3	67	33								3	67	33						.	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in AUGUST.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
QUETTA.																				
	4 km.										**6 km**									
5—10	272	40	6	1	1	2	3	3	10	21	157	42	3	6	8	4	8	6	7	4
10—15									5	6			1		1	1	1		2	1
15—25										1							1		1	1
25—40																	.	..	.	1
	8 km										**10 km.**									
5—10	93	32	2	4	4	3	5	11	15	3	41	22		7	2	2		12	17	15
10—15			1		1		2	2	3	4						2			10	2
15—25			1					1	2	1								5		2
PESHAWAR.																				
	4 km.										**6 km**									
5—10	207	42	6	1					10	34	172	30	6	2	1	..	2	9	12	13
10—15									1	4			2	1	.	.		1	11	6
15—25				.											.		.	1	..	1
	8 km.										**10 km.**									
5—10	85	12	4	2			2	1	11	6	39	8	3	3			.	5		10
10—15			2	4				5	13	4								5	13	3
15—25	.		1	1				14	12	4							.	8	18	3
25—40								4				.						10	13	.
LAHORE																				
	4 km.										**6 km**									
5—10	251	49	17	2		2	2	1	3	16	182	49	3	1	1	2	6	8	12	3
10—15			2	1					1	4			1			1		4	7	1
15—25																	1		1	
	8 km.										**10 km.**									
5—10	124	31	1	2	2		2	14	11	5	83	31	5	1	1		1	5	13	6
10—15			1					6	12	1							1	8	17	1
15—25							1	3	8	2								4	5	
SIMLA																				
	4 km										**6 km.**									
5—10	188	80	2			9	1			7	119	44		1	4	5	6	17	8	3
10—15		.				1				1							3	4	3	1
15—25																	1	.	1	.
	8 km.										**10 km.**									
5—10	87	26	1	1		2	7	8	14	6	40	23				3		17	13	3
10—15		.	1		1		1	10	7	1						.		10	10	5
15—25								10	1									10	5	
25—40								1										.	3	.
DELHI.																				
	4 km.										**6 km.**									
5—10	20	65	5	10				.		15	4	75	.	.	25		.		.	..
10—15	.		.	5	.	.	.						.	.	..	..	..	.	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in AUGUST.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AHMEDABAD.																				
	4 km.										**6 km.**									
5—10	13	46		15	8	15	15	.	..	.	9	55		22	11		11	.	.	
	8 km.										**10 km.**									
5—10	3	67		.	33	.				.	2	0		.		.		:	.	.
10—15		.	.	..	..				.				.		100	.	.	.	.	.
AJMER.																				
	4 km.										**6 km.**									
5—10	57	58	5	11	9	5	2		2	2	33	33	9	12	18		.			3
10—15	.	..	2					.	.	4			3	3	9	.	..	.	3	3
15—25						2		.								3		.	..	.
	8 km.										**10 km**									
5—10	13	23		8	38		8	.			5	0	..		40	20	.	.	.	..
10—15			.		8	15									40			.		..
AGRA.																				
	4 km.										**6 km.**									
5—10	234	55	5		15	5		1	6	7	161	55	4	4	16	7	1	2	3	1
10—15	..	.	1	.	4	1				1					3	1	..	1	1	2
15—25		.	.							.					1	..		..	..	..
	8 km.										**10 km.**									
5—10	114	41	1	10	25	11			4	1	82	29	7	6	27	11			4	2
10—15				1	4	1			2					1	6	2			1	..
15—25					1	.									1			1		.
ALLAHABAD.																				
	4 km.										**6 km.**									
5—10	3	33			33		33										..	.		..
PATNA.																				
	4 km.										**6 km**									
5—10	62	37	2	2	29	6			3	2	39	62			18	13	3			.
10—15			.	.	10	3		.	2	2					3			3		.
15—25					3															
	8 km.										**10 km.**									
5—10	15	33		.	40	13		7			5	20		40						..
10—15	..			7											20	20			.	..
RANGPUR.																				
	4 km.										**6 km.**									
5—10	8	37	.		13	25					3	67				33	.	.	..	..
10—15	.	.	.		13	.							.				.	.	..	.
15—25	.	.	.	13													.	.	..	.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in AUGUST.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
TEZPUR.																				
	4 km.										**6 km**									
5—10	12	50			17			25			4	50		25		25				
10—15									8							.				
	8 km.										**10 km.**									
5—10	2	50				50														
CALCUTTA.																				
	4 km										**6 km.**									
5—10	105	53		2	10	12	6	5	2	3	54	43		6	20	19	6	2		
10—15	.					6										4	2			
15—25						1														
	8 km										**10 km.**									
5—10	16	31			37	25					7	14			29	14				
10—15	.	.				6									29					
15—25															14					
DACCA.																				
	4 km.										**6 km.**									
5—10	17	35	6			29	12		12		5	60				40				
10—15					6															
	8 km										**10 km**									
5—10	2	0			50	50														
CHITTAGONG																				
	4 km										**6 km**									
5—10	14	43			21	29					3	33			67					
10—15	..	.				7														
	8 km										**10 km**									
5—10	1	0			100															
AKYAB																				
	4 km.										**6 km**									
5—10	56	52	2		5	23	7	2	2		28	46			21	11	4			
10—15	..				2	7									4	14				
	8 km										**10 km**									
5—10	9	22	.	11	22	22					4	0			75					
10—15					22															
15—25		.													25			.		
MANDALAY.																				
	4 km										**6 km**									
5—10	40	83		3	5	7					24	58		8	21	4				
10—15								3							4			4		
	8 km.										**10 km**									
5—10	5	60		20							3	33		33			33			
10—15	..				20															

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in AUGUST.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
RANGOON.																				
	4 km										6 km.									
5—10	17	47						12	24		2	0		.	50		50	..	..	..
10—15								6	12							..		.	..	..
	8 km										10 km.									
5—10	1	0			100						1	0						.	..	..
10—15																		..	..	..
15—25															100			.	.	..
JUBBULPORE.																				
	4 km										6 km.									
5—10	23	61	9		4	4	4	4	9		12	83			8			8		..
10—15																	.		..	..
15—25								4									.	..	.	..
	8 km										10 km.									
5—10	3	100									1				100				..	..
RANCHI																				
	4 km										6 km.									
5—10	4	50						25	25									.	..	..
SAMBALPUR.																				
	4 km										6 km.									
5—10	8	75			13				13		4	50			50		.	..	..	..
	8 km										10 km.									
5—10	1	0			100						1	0								
10—15																			.	
15—25															100				..	..
POONA.																				
	4 km										6 km.									
5—10	10	80	10	10							3	33		67			..	..	..	.
HYDERABAD																				
	4 km										6 km.									
5—10	19	32					[illegible]	5	26	11	10	80					..		..	10
10—15									11	5							.	..	..	..
15—25									[illegible]									.	10	..
	8 km										10 km.									
5—10	3	33		33	33									.	.	..	..	..	..	..

n represents the total no. of observations,
and C represents the percentage number of cases where speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in AUGUST.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
WALTAIR.																				
	4 km.										6 km.									
5—10	21	33				5	5		5	19	7	57	.		29				.	..
10—15			5		.				14	5	.		.	..	.	.	.	..	..	..
15—25			5						5					.	.	.	..	.		1
	8 km.										10 km.									
5—10	1	0			100					.						.	..		..	..
MANGALORE																				
	4 km.										6 km.									
5—10	1	100									1	100						..	.	
BANGALORE																				
	4 km.										6 km.									
5—10	43	49				2			21	19	18	62	6	..	6		.	.	11	6
10—15									5	5								6	6	.
	8 km.										10 km.									
5—10	4	50				25			25		3	33								
10—15															33				.	..
15—25															33	.				
MADRAS.																				
	4 km.										6 km.									
5—10	105	26		1				6	31	13	42	67	2	2	5			12	5	5
10—15						1			16	2								2		
15—25									2										.	..
25—40									1								..			.
	8 km.										10 km.									
5—10	16	50	6	6	6	6			6		8	0		13						.
10—15					13										13	25	13			
15—25					6										25	13				
PORT BLAIR.																				
	4 km.										6 km.									
5—10	25	32			8	4	12	16	24		11	45			9		18	9	.	9
10—15									4							.	.	..	9	..
	8 km.										10 km.									
5—10	4	50			25						1	0		.	.	.	.		.	
10—15			.		25						.				100					
TRIVANDRUM.																				
	4 km.										6 km.									
5—10	7	0	.	.		.					.	.			..	..	.	..	.	..
10—15	.		14		..	.	.	.	.	86	••	.	.			.	.	..	.	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

ADEN.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	43	16	5	30	9					5
10—15				20	5					
15—25	..	..	2		2		..	.		

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	27	4	11	19	7					.
10—15			4	30	11				..	.
15—25				15				.	..	..

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	6	33		17	17	17				
10—15				17	.			.	.	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	2	0		.	50	50	.	.		.
10—15			.		.		..		..	..

BAHREIN.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	73	29	11	16	8	14	1	1		7
10—15			4		3	1				3
15—25	.									1

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	53	32	8	17	8	9	2	4	2	11
10—15			2	2	2					
15—25					2			.	.	..

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	24	63	4	4	4			4		8
10—15			4	4	4	.		.		
15—25			..							

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	11	45	9						27	
10—15								9		
15—25			9						..	.

MUSCAT.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	99	22	7	21	15	2				2
10—15		..	1	19	8					1
15—25			1							

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	46	57	7	9	4				2	'
10—15			4	7	2					
15—25									.	

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	18	44		6	11				28	11
10—15										

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	7	14		..	14				14	
10—15	.			..				.	57	

GWADOR

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	34	38	6	18		3		.		6
10—15	..		6	15						
15—25	..		..	9						

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	13	31	15				8	..	.	15
10—15			8	15	8				.	..
15—25				..						..

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	2	50								
10—15		.							50	
15—25	..									

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	1	0					.	..		..
10—15							.	..	.	..
15—25							..		100	..

KARACHI.

4 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	95	22	7	25	12					1
10—15	..		3	14	5					1
15—25			1	8						

6 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	67	36	7	9	4			3	7	1
10—15	.			10		1		1	6	3
15—25			1	3	4		.	..	.	..

8 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	27	26	4	19		4	'	7		4
10—15	.				4			11	4	7
15—25	..	..		..	..	.		4	7	
25—40	..		.	.	..	.	.	.	..	

10 km.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW
5—10	14	57	7	.			.	14	7	..
10—15						..	..	7	..	..
15—25	.		..	.	..	.	..	..	..	..
25—40	.			.		.	..	..	7	..

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PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
QUETTA																				
	4 km										**6 km.**									
5–10	308	53	3	2	1	1	3	5	6	11	213	38	7	1	3	1	4	6	13	8
10–15			1					1	3	7			1					2	6	4
15–25									1	2				1					1	2
	8 km										**10 km.**									
5–10	122	11	3			2	1	2	11	11	43	10		5	2				14	2
10–15			2				2	3	20	3								7	14	
15–25								2	20	2									19	
25–40								1	2	1								2	16	
PESHAWAR.																				
	4 km										**6 km.**									
5–10	242	47	4				1	4	14	28	216	36	4		2			2	16	18
10–15									2	2			1					3	9	5
15–25																		1	2	1
	8 km.										**10 km.**									
5–10	123	2	1	2	1			2	15	7	72	0	1	1					3	
10–15								2	16	6			1					1	13	4
15–25			1					5	24	7								3	24	6
25–40								1	2	3			1					7	31	1
>40																			1	1
LAHORE.																				
	4 km										**6 km.**									
5–10	357	44	17	1	1		1	3	7	18	306	22	4					14	19	12
10–15			2						3	3			2					9	8	5
15–25																		1	2	2
	8 km.										**10 km.**									
5–10	207	7		1				3	8	7	120	4	1		1	1		3	8	4
10–15			1					5	18	5			1	1	1			3	10	4
15–25								7	24	3								4	27	2
25–40								6	2	1								4	17	
>40																		2		1
SIMLA.																				
	4 km.										**6 km.**									
5–10	286	75			1	8	3			9	210	30			2	2	3	19	18	5
10–15						1				2							1	7	7	3
15–25																	1	1	1	
	8 km										**10 km**									
5–10	188	13	1		1	1		5	12	2	99	8	3			2	1	2	6	3
10–15			1					5	10	1								3	11	4
15–25			1				1	10	18	1								6	26	
25–40								1	5	1								6	10	6
>40	.																		2	

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and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
DELHI.																				
	4 km.										**6 km**									
5—10	28	71	4		4		11	4		4	11	64							9	
10—15										4							9	9		
15—25			.															.	9	
	8 km.										**10 km.**									
5—10	2	0							50		1	0			.					
10—15								50											.	
15—25																		100		
AHMEDABAD																				
	4 km										**6 km.**									
5—10	69	59	3	9	12	3				3	19	57	4	14	10	2			4	
10—15				1	9					1				4	4					
	8 km.										**10 km.**									
5—10	20	65		5	5			5	10	5	12	67		8	17			8		
10—15					5															
AJMER																				
	4 km.										**6 km.**									
5—10	102	46	10	12	3	1	7	4	3	3	80	13	5	7	4	1	6	7	7	4
10—15			1	8	2					1			1	4			4	3	1	1
15—25														1						
	8 km.										**10 km.**									
5—10	4	33	10	7	3		5	7	10		21	38	5	10					5	10
10—15			3	7				3	3					5				14		
15—25									5	3				5				5		5
25—40										3										
AGRA																				
	4 km										**6 km**									
5—10	313	55	10	1	1	2	2	3	6	11	288	15	3	1	1	2	2	9	15	6
10—15			2					1	1	2					1			4	7	
15—25																		2	1	1
	8 km.										**10 km**									
5—10	224	33	2	2	2	2		9	10	5	173	36	1	1	3	1	2	7	8	3
10—15			1		1	1		5	9	[illegible]					1	1		8	11	2
15—25								6	6									5	8	
25—40									1									1	2	
ALLAHABAD																				
	4 km										**6 km**									
5—10	15	47		7	7			13		7	8	50			13			13		
10—15								13							13					
15—25					7										13					
	8 km.										**10 km.**									
5—10	5	40			20															
10—15						40														

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
PATNA.																				
	4 km.										6 km.									
5—10	84	67	2		5	1	4	6	11	1	62	63		.	2	2	5	15	8	
10—15				.			1	1	1									5		.
15—25													.					2		.
	8 km.										10 km.									
5—10	29	41	3	3	10	3	3	14	7		10	40	.				30		10	
10—15	.							7	7						10					
15—25				.											.				10	
RANGPUR.																				
	4 km.										6 km.									
5—10	14	71						21	7		12	42			8			25	17	
10—15																		8	.	.
TEZPUR																				
	4 km.										6 km.									
5—10	14	79						7	14		8	87	..			..	.	..	13	.
	8 km.										10 km.									
5—10	3	100			.		.				1	100	..	..			.			
CALCUTTA																				
	4 km.										6 km.									
5—10	157	57			6	14	7	6	6	2	87	54	1		15	7	6	3	5	1
10—15					2	1	1		2							3	.		1	
15—25													..		3					.
	8 km.										10 km.									
5—10	41	46		5	12	17	2	5		2	16	44	6	.	6	6	6		6	.
10—15	.				5	2								.		19	6		.	
15—25					.					2								..		
DACCA.																				
	4 km.										6 km.									
5—10	26	67		.	8	12	4	8	4		8	75				..	..	25		
CHITTAGONG.																				
	4 km										6 km.									
5—10	32	63			9	16	3	3	6	.	18	67	..	.	11	11	6	6	..	
	8 km.										10 km.									
5—10	5	80				20				..	2	100						.	.	

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AKYAB.																				
	4 km.										**6 km.**									
5—10	136	68		1	13	8	4	2	1		86	57		5	16	13	2	1	1	.
10—15					1	3	1									1	1	..	..	
	8 km.										**10 km.**									
5—10	45	44		2	31	9	7				19	37		11	5	32		••		.
10—15					4	2									16				.	..
MANDALAY.																				
	4 km.										**6 km.**									
5—10	51	80			4	8	2	2		2	24	67	4	4	8			8	.	8
10—15				.					2	..				.					.	..
	8 km.										**10 km.**									
5—10	5	60			20					20							.			..
RANGOON.																				
	4 km.										**6 km.**									
5—10	21	62	5		10	5	19				4	100			.				.	..
JUBBULPORE.																				
	4 km.										**6 km**									
5—10	63	60	8	5	8	3		2	5		43	47			19	5	2	14	9	.
10—15				3	2				3	2					2				2	..
	8 km.										**10 km.**									
5—10	20	45			25			10	10	5	11	27		9		18		9		
10—15					5										18		.	9	9	..
RANCHI.																				
	4 km.										**6 km**									
5—10	23	65			9		4	22			16	25	6			13	6	6	37	
10—15																			6	
	8 km.										**10 km.**									
5—10	7	14				14		14	28							.	.	.	..	..
10—15						14		14												..
SAMBALPUR.																				
	4 km.										**6 km.**									
5—10	15	27	7	13	13	13	7		7	..	6	67			17	17		..	..	..
10—15	.	.			7			7		.	••	..	.	.	.	..	..	..	..	••
	8 km.										**10 km.**									
5—10	3				33	33	.				1	100				.	.	.	.	.
10—15					33													.	.	..

n represents the total no of observations,

and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
POONA																				
	4 km.										**6 km.**									
5—10	83	77	2	2	6	5	2	1	1	1	47	74	2	9	6	2	2	2	2	.
10—15	..				1								.		.	..	..	..	..	.
	8 km.										**10 km.**									
5—10	25	52		16	12	4				..	13	46		8	31	8				
10—15					16										8				..	.
HYDERABAD.																				
	4 km.										**6 km.**									
5—10	41	59	10	7	5	2		2	7	5	26	61			19	12	..		4	..
10—15										2					4		.			..
	8 km.										**10 km.**									
5—10	13	38			23	15				8	4	50		.	25	25	..	.	..	
10—15	.				15													.	.	
WALTAIR.																				
	4 km.										**6 km.**									
5—10	41	71	5		5	2	2		5	2	21	57	5	10	19	5	5			.
10—15					5	2														
	8 km.										**10 km.**									
5—10	9	22		22	22	11					4	0			50					
10—15					11										25			.		
15—25				11										25						
MANGALORE.																				
	4 km										**6 km.**									
5—10	16	50		6	13	13			6		5	80								
10—15					6				6						20		.			
BANGALORE.																				
	4 km.										**6 km.**									
5—10	115	58	1	1	6	3		7	11	10	62	69	2		6	3	3	2	5	2
10—15	.	.		..		1		1		1					2	3	.	2		2
	8 km.										**10 km.**									
5—10	25	56		4	28						11	9	..	9	27	9			..	..
10—15	..	..	.		12			..	.	.			.	..	18	9	..		..	..
15—25	..	..				..	..	..	.	..	.	..	.	.	18	..	..	.	..	..
MADRAS.																				
	4 km.										**6 km.**									
5—10	131	52	1	4	8	4	..	5	11	8	91	53	2	2	12	2	4	2	11	2
10—15	..	..	..	..	..	1	.	..	5	2	.	..	..	..	5	3	..	..	..	..
15—25	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..
	8 km.										**10 km.**									
5—10	38	37	.	8	29	3	3	..	.	.	17	12	.		24	6	.	.	.	..
10—15	..	..	..	..	21	..	.	.	..			..	.	..	29		..	..	..	..
15—25	.		.	..	.			..	.						29	.	.	..	..	.

n represents the total no. of observations.

and C represents he percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in SEPTEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
PORT BLAIR.																				
	4 km.										**6 km.**									
5—10	68	53		1	10	9	1	3	12	4	39	64	3	10	13	3		..	.	3
10—15						1	1		3						.	3	..	..	.	..
15—25						..					.		.			.	3	..	.	..
	8 km.										**10 km.**									
5—10	15	20			40	13					9	11			22					..
10—15				17	20										55			.		..
15—25															11					..
TRIVANDRUM.																				
	4 km										**6 km.**									
5—10	20	25	5			10			5	15	1	100							.	..
10—15			15	10						5										.
15—25				5					5					.			.		.	..
	8 km.										**10 km.**									
5—10	1	0	100								1	100					.	..	..	.
10—15																..	..	.	.	.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

ADEN.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	44	14	2	27	7	2					27	22	15	15	7	11	4		4	..
10—15			5	30	2						.			11	4	4			.	.
15—25			2	9											4					
	8 km.										10 km.									
5—10	10	20		10	20						5	20					20			
10—15			10	20	20									20						
15—25															40					

BAHREIN.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km									
5—10	84	25	17		5	5	5	1	5	13	58	17	3	5	5	2	2	5	21	10
10—15			7	1	1	1			2	7								7	10	10
15—25			2							1			2							
25—40																				..
	8 km										10 km.									
5—10	29	14						3	10		12	0								
10—15									31	7									33	.
15—25								3	28									17	25	8
25—40									3										17	

MUSCAT.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	139	40	8	16	14	1	1		4	5	100	25	11	6	4		1	7	9	13
10—15				5	4								2	2	2			1	6	8
15—25				1						1									1	2
	8 km.										10 km.									
5—10	32	13		3	6			9	3	9	12	8						25		
10—15				3				6	16	16									8	..
15—25								3	13									17	25	8
25—40																				8

GWADOR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	71	32	23	8	1		3		7	4	55	13	4		5			2	5	15
10—15			7	6				1	1	1			5		4			5	13	16
15—25			4												2			2	4	5
	8 km.										10 km.									
5—10	6	0		17							1	0								
10—15									33									.		
15—25	.		.					17	33											
25—40	.																		100	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
KARACHI.																				
	4 km.										**6 km.**									
5—10	184	33	14	12	4	1	1	2	3	10	152	20	4	5	1	1	1	3	11	8
10—15			2	8	2		1	1	2	2			5	2	1			5	13	7
15—25			1	5					1				3						8	3
	8 km										**10 km.**									
5—10	83	4		1	2	1		1	11	6	45	11						4	2	
10—15			1					2	14	5								2	9	2
15—25								1	30	10									29	4
25—40								1	5	4									24	7
>40																		4		
QUETTA.																				
	4 km.										**6 km.**									
5—10	315	37	5	1	1		1	1	7	13	180	21	4	1	1	1		2	13	13
10—15			2					1	5	17			4	1	1	.	1	3	7	14
15—25								1	3	4			1		1			1	7	6
25—40																			1	.
	8 km.										**10 km.**									
5—10	85	9	5					5	7	2	29	3	7					7	10	..
10—15			1						16	5								3	10	3
15—25			1					2	22	18									24	10
25—40									5	1									21	..
PESHAWAR.																				
	4 km.										**6 km**									
5—10	258	54	3	2			1	4	11	19	244	21	7	1	1			5	19	13
10—15			1						2	3			2				1	3	12	8
15—25													1						5	2
	8 km.										**10 km.**									
5—10	178	5	4					1	7	11	106	2	1				.	1	1	1
10—15			2					1	16	9			2					2	15	5
15—25			2					3	24	7			3					3	22	10
25—40									4	3								3	21	3
>40									1										7	.
LAHORE.																				
	4 km.										**6 km.**									
5—10	385	33	10	2		2	3	4	9	27	342	10	4	1		1	1	6	18	12
10—15			2					1	2	6			2					4	18	9
15—25								.	1	1								1	7	5
	8 km.										**10 km.**									
5—10	253	3	1					1	7	3	133	2						.	3	1
10—15		.	1			.		1	13	7			1				.	1	3	.
15—25			2		.	.		8	27	10							.	1	30	10
25—40	.	.		.				1	12	3			1					5	35	2
>40	.		.		.											.		4	4	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
SIMLA.																				
	4 km.										6 km.									
5—10	390	54	1		1	7	3	1	2	21	357	17	2				2	9	15	9
10—15	.					2				7		1					2	5	17	8
15—25						1											.	2	8	3
	8 km.										10 km.									
5—10	260	4						2	6	2			.			.			.	..
10—15						[illegible]		3	13	4							.		.	..
15—25						[illegible]		7	32	7										
25—40								3	13	1									.	..
DELHI.																				
	4 km										6 km.									
5—10	35	43			3		9	6	9	20	17	41				6	.		12	.
10—15			3						3	6							.	12	18	.
15—25																		6	6	.
AHMEDABAD.																				
	4 km										6 km.									
5—10	95	47	5	6	4	1	5	4	15	3	74	27	1	1	3			8	11	8
10—15			2	2	1				3				1					3	23	5
15—25																	1		4	3
	8 km.										10 km.									
5—10	21	14						19			10	20						10	20	10
10—15								14	19	24									40	
15—25								10												.
AJMER.																				
	4 km.										6 km.									
5—10	106	37	5	6	4		2	7	11	10	86	14	7	1			2	3	8	12
10—15			8	1	1				4	6			1	1	1		1	3	15	6
15—25													1					5	12	2
25—40																			2	1
	8 km.										10 km.									
5—10	34	0							6	9	14	0								
10—15								9	21	6									29	14
15—25								9	29	3								14	43	
25—40									9											
AGRA.																				
	4 km										6 km.									
5—10	425	30	13		1	1	1	4	12	20	386	11	3				1	6	12	8
10—15			3			.		1	6	6			2				1	3	21	9
15—25			.	.														3	15	4
25—40			.	.								.	.	.			.	1	1	1
	8 km.										10 km.									
5—10	314	4	1		.			1	4	3	192	4	.	.			.	2	5	2
10—15			1	.				3	11	4					.	.		2	8	2
15—25	..			.	.	.		8	32	7					.	..	.	7	26	3
25—40	..				.	..		3	16	2	.		.	..	..	.	.	4	26	1
>40	..	..		..	..	..	..	.	..	..	.	..	.	..	..	..	..	2	9	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

ALLAHABAD

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	30	33	3		3			13	13	3	20	20				5		10	5	.
10—15		.					3	7	3	17								5	15	.
15—25																.		5	35	..
	8 km.										**10 km.**									
5—10	3	33									1	0							.	
10—15																			100	
15—25									33	33					.					

PATNA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	92	35		1	1	1	2	9	13	8	74	14		1	1			5	14	3
10—15					2			10	10	2			1		3		1	5	19	1
15—25					1			1	2	2					1		1	4	24	1
	8 km										**10 km.**									
5—10	19	16					5				2	0						50	.	
10—15								5										50		..
15—25								5	42	5										.
25—40									21											

RANGPUR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	17	41						12	6		16	19						6	13	6
10—15									24	6								19		.
15—25									12										31	.
25—40																			6	.
	8 km.										**10 km.**									
5—10	1	0										.					.		..	..
10—15								100								.	..	..	..	..

TEZPUR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	9	44	.		.			.	33		3	33	.	..	.	..	..	..	67	..
10—15	..		.	.				..	11	.	.	..	..	..	.	..	.	..	..	..
15—25	..	.	..		.	.		.	11	..	..	..	..	.	..	..	..	..	..	..
	8 km.										**10 km.**									
5—10	1									100			.	.	..	.	..	..	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
CALCUTTA.																				
	4 km.										**6 km.**									
5—10	244	29	2	2	2	4	3	11	21	7	164	24	1	1	2		2	7	19	5
10—15					1	1		3	7	1				1		1		5	16	5
15—25					1			4										1	9	1
	8 km.										**10 km.**									
5—10	61	11	2		3		2	3	15	3	17	29		6						.
10—15	.						2	8	18	3					.			12	18	.
15—25								5	20	2								12	24	
25—40									3											
DACCA.																				
	4 km.										**6 km.**									
5—10	72	33	4		1	1	1	8	24	1	40	30						5	10	3
10—15							1		21								5	5	23	3
15—25	.								3										15	3
	8 km.										**10 km.**									
5—10	4	0																		
10—15								25	25											
15—25									25											
25—40									25								.		..	
CHITTAGONG.																				
	4 km.										**6 km.**									
5—10	52	50	.	2	2	2	4	6	23		29	45		3		3	3	14	7	7
10—15								2	10									7	10	
	8 km.										**10 km.**									
5—10	4	0							25	25	1									..
10—15	..							25											100	
15—25	..							25												
AKYAB.																				
	4 km.										**6 km.**									
5—10	239	61	1	2	4	5	5	7	10	3	167	48	1	2	5	3	4	5	13	5
10—15			..					1	2				1		1	1	1	1	5	2
15—25															1			1	1	
	8 km										**10 km.**									
5—10	92	28	1	.	7	7	2	7	9	4	59	17	5	2	3	2	2	12	17	
10—15	..	.		1	.	3	.	5	7	2					2	3		7	10	.
15—25	..	..		..			.	..	4	2		.	.			2	..	3	10	..
25—40	..	.	..		.				1				.			.	.	2	2	.
MANDALAY.																				
	4 km.										**6 km.**									
5—10	73	48	.	.	3	1	7	8	27		34	32	.	.	.	6	9	6	18	6
10—15	.	.	..	..		.	.		5	.		.	..	.			3	3	18	..
	8 km.										**10 km.**									
5—10	7	14	..		14	14														.
10—15	..	..	..	14		.	..		29			.		.				.		..
15—25	..	.	..	.	.	.	.	.	14	.		..	.							.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
RANGOON.																				
	4 km.										**6 km.**									
5—10	59	80		5	5	3			2		29	73		14	3	3	3			3
10—45					3	2										.				..
	8 km										**10 km.**									
5—10	8	50	25	13				13											.	..
JUBBULPORE.																				
	4 km.										**6 km.**									
5—10	90	35	9	6	6	2	1	12	19	4	69	25	1	4	1	1		14	26	3
10—15					1				2	1								6	9	4
15—25										1								1	1	1
	8 km.										**10 km.**									
5—10	17	6						18	18		4	25							25	..
10—15								6	12									25	25	..
15—25								18	24											.
RANCHI.																				
	4 km										**6 km**									
5—10	17	35					18	6	35	6	15	20					7	7	20	..
10—15																			40	7
	8 km										**10 km.**									
5—10	2	50							50											..
SAMBALPUR.																				
	4 km.										**6 km.**									
5—10	31	58	3		3		3	16	6	6	25	56					4		24	1
10—15			3															4	8	..
	8 km										**10 km**									
5—10	10	30	10					10	20	10	2	50								
10—15									10											50
15—25										10										.
POONA.																				
	4 km.										**6 km.**									
5—10	156	74	5	8	4	1		1	3	1	113	62	4	2	4	4	1	5	8	6
10—15				1		1				1				3					2	.
15—25																.			1	..
	8 km										**10 km.**									
5—10	75	48	1		5	3	1	8	20	1	49	22			4	6	4	6	10	2
10—15								1	5	3				4	2	2		8	16	2
15—25									3									.	10	..

n represents the total no of observations,

and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

HYDERABAD.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	59	66	5	5	5	3		5	2	7	52	75	6		8	6	2	2		2
10—15									2											.
	8 km										10 km.									
5—10	33	64	6	3	9	6		3	6		10	50			20	20				
10—15			.	3											10					..

WALTAIR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	78	72	3	3	6	8		3	1	1	55	69	2	4	11	11	2			
10—15			1			1		1							2					
	8 km.										10 km									
5—10	20	70		5	10	10			5		9	44			22				11	
10—15																			11	
15—25			.											11						

MANGALORE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	37	35	3	3	27	5	5		5		13	38		8	23	23			8	
10—15					8	3														
15—25					3															

BANGALORE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km									
5—10	205	59	2	6	12	4		3	3	4	130	54	1	6	20	2	2		3	2
10—15		.			3				1	1			1	1	8	1				.
	8 km										10 km.									
5—10	72	42	1	11	24	10	4		1		35	54			17	11	3	6		
10—15	..		.		4	1									9					
15—25					1															

MADRAS.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	123	60	3	2	12	3	2	3	3	5	82	68	1	4	15	2	1	1	1	1
10—15					4				2						6	..				
	8 km										10 km									
5—10	31	49	3	6	23	6	3				14	29			21	7	7			
10—15	.				6	3									14	7				
15—25															14					

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in OCTOBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
PORT BLAIR.																				
	4 km.										6 km.									
5—10	81	57	2	7	15	1	5	2		5	48	50	2	10	29	2	4	.	.	..
10—15							2	1	1							2	..		.	..
	8 km.										10 km.									
5—10	25	24		20	28	12	8			4	13	23			31	23	.	.	..	8
10—15		.			4									8	8			.	.	..
TRIVANDRUM.																				
	4 km.										6 km.									
5—10	26	27	4	8	4			4	12	8	6	67							17	..
10—15								4	15	4								17	.	..
15—25				4						4									.	..
25—40						4													..	..
	8 km.										10 km.									
5—10	2	50				50													..	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ADEN.																				
	4 km										**6 km.**									
5—10	57	42	7	12	12	5		2		2	41	44	10	5	5	12	5			2
10—15			4	7	4		.			4				5	2	2	.		.	
15—25																			5	
25—40													2						..	
	8 km.										**10 km.**									
5—10	15	17	13	7	7	7		7	7		5	20								20
10—15			7									.						20	20	.
15—25																		20	.	
BAHREIN																				
	4 km										**6 km**									
5—10	89	28	1					8	19	17	59	7						8	8	7
10—15								4	8	12								2	22	8
15—25					1	1												8	22	5
25—40																			2	
	8 km.										**10 km.**									
5—10	18	11						6	11	11	5	0								
10—15			6				6		6	6										
15—25									28										40	40
25—40									11									20	..	
MUSCAT.																				
	4 km										**6 km.**									
5—10	127	43	5	2	2		3	11	9	9	83	11	2				1	7	16	4
10—15				1				6	4	3								8	16	8
15—25									2									5	13	7
25—40																			1	
	8 km										**10 km.**									
5—10	21	0						5	5		10	0						10		.
10—15								14	10										10	..
15—25								14	14	10								30	20	
25—40								14	5	10								10	10	
>40																				10
GWADOR.																				
	4 km.										**6 km.**									
5—10	110	38	4		1		3	10	17	14	87	3						5	13	8
10—15				1				8	2				1					13	23	7
15—25								1		1			1				1	3	15	6
25—40																	.	1		
	8 km										**10 km.**									
5—10	17	0							12		6	0							.	..
10—15							6	6	18										..	..
15—25			.					12	29	12										..
25—40	.							6	6									33	67	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

KARACHI.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										**6 km**									
5—10	201	34	7	2			1	5	15	11	174	6	1					2	12	7
10—15			2	1				3	8	4			1				1	4	17	10
15—25								1	2	1								6	22	7
25—40													1						2	1
	8 km										**10 km.**									
5—10	82	0						2	2	1	39	0								
10—15								1	4	4										
15—25								4	32	8									21	3
25—40								5	26	5								8	49	
>40									2	2									21	

QUETTA.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										**6 km.**									
5—10	304	24	3				2	5	15	13	176	5	2	1				7	8	7
10—15			2	1				1	8	15			1					3	24	7
15—25			1						2	6	..							2	16	9
25—40																			2	5
	8 km.										**10 km.**									
5—10	71	3	1				1		3	1	9	11						11		
10—15			.					1	8	6									11	
15—25								7	30	7								11		
25—40								3	23	3									44	..
>40									3	..									11	..

PESHAWAR.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km**									
5—10	245	49	2	1			1	7	19	13	215	8	2	2		1		5	12	11
10—15			2						2				2	1				2	19	10
15—25		.							1				1	1				1	15	4
25—40																			1	
	8 km.										**10 km.**									
5—10	142	4	1	1				4	8	4	80	0		1				1	..	6
10—15				1			1	1	10	4			1				1	4	5	4
15—25			3					1	24	11			1	1				3	29	10
25—40			1					1	16	3									16	13
>40									1										3	1

LAHORE.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	397	32	5		1		2	5	16	21	356	4	1	1	..		1	3	11	10
10—15			2					2	5	6			1					4	17	9
15—25										1			1				1	2	25	6
25—40						.												1	2	2
	8 km.										**10 km.**									
5—10	257	1				1		1	4		125	2						.		..
10—15	.							1	10	4			1					1	3	1
15—25			1					4	28	12								2	22	4
25—40	.					.		1	25	4								5	31	10
>40	..	.				.			2								.	2	18	.

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

SIMLA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	378	55	1	1	1	6	6	1	6	15	325	7	2				1	6	11	6
10—15			1			2	1		1	3			1				1	7	18	9
15—25																	.	4	18	7
25—40																			2	1
	8 km.										**10 km.**									
5—10	211	1				.			2	1	88	7								1
10—15								2	6	3			1						.	..
15—25								3	23	9								1	16	7
25—40								9	29	5			1					7	27	7
>40									4									2	20	2

DELHI.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										**6 km.**									
5—10	44	14	2					7	25	30	14	0							14	7
10—15									16	7										
15—25																			57	7
25—40														.				7	7	

AHMEDABAD.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	116	47	5				2	3	22	10	101	14	1					9	12	4
10—15			1					4	3	1			1				1	3	17	8
15—25								1										6	16	7
25—40																	.		2	
	8 km.										**10 km**									
5—10	29	0							14	7	3	0								
10—15								10												.
15—25			3					14	41	7	.							33		33
25—40								3			.								33	.

AJMER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										**6 km.**									
5—10	114	19	5				1	8	21	9	84	4			.		..	4	4	1
10—15								2	20	7							1	2	18	11
15—25								2	3	3			1			.	1	8	31	5
25—40								1										1	6	2
	8 km.										**10 km.**									
5—10	19	0									1	0								..
10—15										5										..
15—25									26	16								.	..	.
25—40	.							11	26	5								..	..	100
>40		.							11								.	..	..	.

AGRA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	412	16	2					5	20	17	362	3					.	2	3	2
10—15			1					3	17	8			1					3	20	7
15—25									5	3			1					4	33	10
25—40			.											.	.	.	..	1	8	1
	8 km.										**10 km.**									
5—10	284	0							1	1	138	0		.	.			.	1	..
10—15	..	.	.	.					3	1			1	.					12	5
15—25			1		..			5	24	8					.	..	.	7	38	7
25—40	..	.	..	.	..	.	.	4	44	6			1		.			1	27	..
>40	..	..	.		..	..	..	..	2				..					..	1	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
ALLAHABAD.																				
	4 km.										**6 km.**									
5—10	19	11	5			..		5	5	21	7	0								.
10—15								5	21	16	..	.							14	
15—25			5						5										43	29
25—40																			14	
	8 km.										**10 km.**									
5—10	1	0														.				.
10—15	.																			.
15—25																				.
25—40									100										..	.
PATNA.																				
	4 km.										**6 km.**									
5—10	106	6	1						10	12	90	0							4	1
10—15		.	1						25	17							.	1	14	2
15—25									12	15								1	49	10
25—40	..																	2	8	7
	8 km.										**10 km.**									
5—10	19	0							5		2	0								
10—15								5		5										
15—25								11	26	11									50	50
25—40									37											
RANGPUR.																				
	4 km.										**6 km.**									
5—10	26	4			4				4	4	7	0								
10—15			4						35	15										43
15—25									19	8									43	
25—40									4										14	
TEZPUR.																				
	4 km.										**6 km**									
5—10	15	20						7	33		12	8							.	..
10—15					7			13	13										25	
15—25									7										50	8
25—40																			8	.
CALCUTTA																				
	4 km.										**6 km.**									
5—10	263	13	2				1	7	27	11	201	3			.			3	8	3
10—15								3	20	9								6	30	11
15—25									2	5								2	28	3
25—40															.				1	
	8 km										**10 km.**									
5—10	51	0						2	6	2	9	0								
10—15								4	22	6									11	
15—25	.	..		.			.	5	50	4					.			.	89	
25—40									2										.	

n represents the total no of observations,

and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

DACCA.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km**									
5—10	85	7		2		.	..	1	19	7	45	9								4
10—15								1	41	4						..		4	22	2
15—25								1	8	7								4	35	7
25—40									1										11	.
	8 km										**10 km.**									
5—10	2	0																		
10—15																				
15—25									50											
25—40									50											

CHITTAGONG

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										**6 km.**									
5—10	64	16	2					6	23	5	30	7	3				3	7	20	
10—15								2	34	5									30	7
15—25									6	2								3	20	
	8 km										**10 km.**									
5—10	6	0							33		1	0								
10—15									17											.
15—25									50									100		

AKYAB.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										**6 km**									
5—10	255	40	2		1	1	2	11	22	9	196	21	2	1		1		9	21	5
10—15							2	3	6	3			1				1	2	20	9
15—25																		1	6	2
	8 km										**10 km**									
5—10	118	17		1				11	9	5	60	7					2	10	13	3
10—15								4	14	5								5	22	2
15—25			1					4	19	7								3	22	2
25—40									2	1									10	

MANDALAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										**6 km.**									
5—10	62	11			.			8	34	8	31	10						10	15	3
10—15								2	26	5									42	
15—25									5	2									13	3
25—40																			3	
	8 km										**10 km.**									
5—10	2	0																		
10—15									100											.

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
RANGOON.																				
	4 km.										6 km.									
5—10	60	67	5	3	2	3		3	7	3	35	57		9			3	9	11	9
10—15		.	2		3	2									.	.	..	.	3	..
	8 km.										10 km.									
5—10	8	0						25	13	25	4	0								..
10—15		.							25										25	..
15—25		.						13										.	50	.
25—40				.													.	.	25	..
JUBBULPORE.																				
	4 km.										6 km.									
5—10	107	26	5		1		1	6	21	17	90	2	1	.			1	4	12	14
10—15			2						10	8								3	24	10
15—25									3								1	3	14	3
25—40																		1	2	1
	8 km.										10 km.									
5—10	14	0								14									.	.
10—15								14	21									.	.	.
15—25								14	36											..
RANCHI.																				
	4 km										6 km.									
5—10	30	10							20	7	15	7							7	..
10—15									23	17									40	7
15—25									7	17									33	
25—40																		.		7
SAMBALPUR.																				
	4 km.										6 km.									
5—10	41	39	2		2		2	2	22	12	34	21	3			3		3	21	9
10—15								2	5	10								3	21	6
15—25							.	.										.	12	..
	8 km.										10 km.									
5—10	9	0		..			..	..	.		2	0		.		.		.		.
10—15	.	..	.	.	.	..	..	..	..	..			.	..	.	..	.	..	..	..
15—25	..	..	..	.	..	.	..	..	78	22	.		..	..			..	..	50	50
POONA.																				
	4 km.										6 km.									
5—10	181	58	5	8	4	2	2	1	6	8	167	44	5	1	2	4	4	7	5	6
10—15	..	..	1	1	1	1	..	1	.	1	..	.	3	1	..	1	.	2	8	5
15—25	..	.	..	.	..	..	.	1	..	..	.	..	..	.	.	..	..	..	1	2
25—40	..	..	.			.	..	..		..	..	..	.	.	..	..	..	1	..	..
	8 km.										10 km.									
5—10	117	12	4	1	.	2	4	9	15	8	57	4		.	..	..	2	7	9	4
10—15			3	.			2	10	10	3							.	11	16	4
15—25	.		1					2	13	3							2	25	12	4
25—40	..			.														2	..	2

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
HYDERABAD.																				
	4 km.										**6 km.**									
5—10	70	61	4	13	9	7				3	60	55	10	3	7	7		2	2	7
10—15		..	.	3									3		2	2			2	
	8 km.										**10 km.**									
5—10	44	45		2		2	7	14	2	7	18	11				6	6	11	11	
10—15			7	.				2	2	7						6		17	11	
15—25		.			.			2										11	6	
25—40											.							6		
WALTAIR.																				
	4 km.										**6 km.**									
5—10	91	75	1	4	4	1		3	5	3	69	52	6	1	7	3	3	3	6	14
10—15	..		.	.				1							1			3		
15—25	..	.		1																.
	8 km.										**10 km.**									
5—10	24	25					.	4	13	13	4	50								
10—15					4	4	..		25	8										50
15—25	.	.	.				..	4									.			.
MANGALORE.																				
	4 km.										**6 km.**									
5—10	70	46	1	13	21	3		1	7		33	27		12	36	3			..	
10—15					7									9	6					.
15—25	.												3		3					
	8 km.										**10 km.**									
5—10	5	20	..	20	40	.	20				1	0						100		.
BANGALORE																				
	4 km.										**6 km.**									
5—10	200	55	1	11	18	1	2	1	3	1	148	41	3	9	21	4	1		2	1
10—15	.	.		2	5								3	2	9	1				1
15—25	.	.		.	1	.								1	1	..			.	..
	8 km.										**10 km.**									
5—10	71	49	3	1	6	3	6	4		1	49	27	4	2	6	4	8	6	..	2
10—15	..	.		1	1	1	..	8	4					2	2	2	2	12	6	..
15—25	..	..	.		1			6	1	1	.	.	..	..	2	.	..	8	2	2
MADRAS.																				
	4 km.										**6 km.**									
5—10	97	57	3	8	21	3	.	.	1	..	63	30	3	11	21	2	.	3	2	3
10—15	..	..	1	1	2	1	1	..		1	.	..	2	6	13	2	..	.	..	..
15—25	..	..	.	..	..	.	..	..	.	..	..	..	3	..	..	..	..	..	..	..
	8 km.										**10 km.**									
5—10	30	53	3	13	10			3	3		15	33		7	13	7	7	13	13	..
10—15	..	..	..	7	3	.	.	.		.	.			.	..	.	..	..	..	..
15—25	..	..	..	3	.	.	.	..	.	..		.	..	..	..	..	..	7	..	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in NOVEMBER.

PORT BLAIR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	59	44	2	7	25	8	2	3			42	33	5	17	26	2	2	..	.	..
10—15				5	2									2	5		..	.	.	..
15—25					2									2	2				.	..
	8 km.										10 km.									
5—10	20	55		15	10	5			5		12	33		25	8	8		..	8	..
10—15						5											8		.	..
15—25																				..
25—40				5						.				8				.	..	..

TRIVANDRUM.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	28	50		11	7	11	4	4	4	4	14	71		7	7		7			..
10—15						4				4					7					..
15—25																				..
	8 km										10 km.									
5—10	5	60							20		1	0				100				..
10—15	..																		.	..
15—25					20															..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER

ADEN.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	41	32	2	10	10				10	2	26	19		8	4	4	8		..	4
10—15				10	15	2								8	12	8	4			
15—25					7									12	12					.
	8 km										10 km.									
5—10	5	20	20					20	20		3	0					33			.
10—15									20									33	33	

BAHREIN.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km									
5—10	75	5	4	1				8	15	12	41	0	2						2	5
10—15									17	12									22	7
15—25								1	17	7									41	10
25—40	.																		10	
	8 km										10 km.									
5—10	8	0									1	0					.			
10—15									13											
15—25									13	25										.
25—40									50											100

MUSCAT.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	97	9		1				3	19	13	46	0							4	9
10—15			1					5	21	11									17	11
15—25			1						8	7			2					7	26	20
25—40																			4	
	8 km										10 km.									
5—10	10	0							10		4	0								
10—15										10										
15—25									40										25	25
25—40	.									40										50

GWADOR.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km										6 km.									
5—10	102	6	2					4	15	10	60	0						3	8	5
10—15			1		1			6	22	15			2					3	23	8
15—25									12	4								2	21	15
25—40									4									2	3	3
	8 km.										10 km.									
5—10	8	0									3	0								
10—15									25			.								
15—25									13	13										.
25—40										50		.								33
>40																			..	67

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
KARACHI.																				
	4 km.										6 km.									
5—10	200	16	3	1			1	7	13	8	165	3	1				.	1	3	1
10—15	.		1					7	16	7			2					1	12	6
15—25			1					5	11	5			1					9	35	10
25—40									1									4	7	4
>40																			1	..
	8 km										10 km.									
5—10	74	4						1			32	3								3
10—15			4					1	7	1								3	3	.
15—25			3					4	19	5			3					3	19	
25—40								5	31	8								3	25	
>40								1	4									3	22	..
QUETTA																				
	4 km										6 km.									
5—10	260	17	2				2	6	16	8	98	1	1					3	14	5
10—15			2			..		4	13	8			3					3	16	7
15—25			1				..	3	7	9							.	1	29	7
25—40							..			1							..	1	8	
	8 km										10 km.									
5—10	25	4	4						4	4	8	25								13
10—15			4		.				16					.					13	.
15—25									36	12			13						13	
25—40								4	8	4								13	.	..
>40	..																		13	.
PESHAWAR.																				
	4 km										6 km.									
5—10	253	47	2	1		3	3	7	13	11	204	8	3				2	6	..	6
10—15				1			1	2	3	2								8	17	6
15—25			1			..		1	1				1				1	5	18	8
25—40																		1	1	..
	8 km.										10 km.									
5—10	103	3		1				2	3	3	42	0							2	.
10—15			1				1	2	6	8									14	
15—25			1				1	4	22	17			2					.	14	21
25—40								3	15	7								2	26	12
>40	.	..							1	1									5	
LAHORE.																				
	4 km.										6 km.									
5—10	359	23	1	1			4	15	16	9	276	2		.			1	1	6	4
10—15			1				1	5	11	8			1				1	5	19	5
15—25							1	1	1	1								9	28	8
25—40																		1	6	4
	8 km.										10 km.									
5—10	161	1	.					1	1	1	53	0					..		2	..
10—15			1				1	1	9	2			2				..	..	4	..
15—25				..		.	.	4	22	9							..	.	25	6
25—40	.	.		..	.	.	.	4	29	9		.			.		..	2	32	11
>40	.	.	.	.	.				5	2	.				.		..	.	13	4

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
SIMLA																				
	4 km.										**6 km.**									
5—10	361	40	1		2	6	9	6	7	15	259	4						5	5	4
10—15						1	2	1	2	6							.	10	20	7
15—25							1			1							1	5	24	7
25—40																	1		5	2
	8 km.										**10 km.**									
5—10	131	2							2	2	44	5	2							.
10—15			1					2	3	4									2	7
15—25								2	26	7			2					2	14	7
25—40								5	34	6									23	5
>40								1	5									2	29	
DELHI.																				
	4 km										**6 km**									
5—10	60	7		2				8	22	7	23	0						4	4	
10—15			.					3	30	5								13	13	9
15—25								2	10	3									35	
25—40									2										13	9
AHMEDABAD.																				
	4 km.										**6 km.**									
5—10	103	16	2			..	3	10	17	3	72	0						3	3	
10—15			1				1	9	19	4								3	24	7
15—25								2	10	3								11	35	1
25—40									2										8	9
	8 km.										**10 km.**									
5—10	14	0				.					2	0							.	.
10—15																				..
15—25								14	50	7									50	.
25—40									29										50	.
AJMER.																				
	4 km.										**6 km.**									
5—10	104	9	3		.		1	4	10	5	63							3	3	2
10—15								5	34	5								3	6	5
15—25								4	16	5								8	37	10
25—40								1										2	19	3
	8 km.										**10 km.**									
5—10	8	0						.		13	2	0							.	..
10—15							.		13	13							.	..	..	..
15—25				.					37	13								.	.	50
25—40			.					..	13		.				.			.	50	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

Speed limits m/s	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
AGRA.																				
	4 km										**6 km.**									
5—10	419	8	1					6	18	7	362	1							4	1
10—15								6	24	8								1	12	5
15—25								4	12	4								9	38	7
25—40																		4	14	3
	8 km										**10 km.**									
5—10	242	0	1							1	77							1		1
10—15								1	2										1	3
15—25								2	21	6									10	3
25—40								3	46	5			1					1	32	9
>40									9	1									31	5
ALLAHABAD.																				
	4 km.										**6 km.**									
5—10	14	21							21		5	0							20	
10—15									14	29									20	20
15—25									7	7										20
25—40																			20	
	8 km										**10 km.**									
5—10	2	0																		
10—15																				
15—25									50	50										
PATNA																				
	4 km										**6 km**									
5—10	102	5		1					20	6	66	0							2	2
10—15								2	25	5									24	2
15—25									21	13								11	29	6
25—40									3	1									18	6
>40																			2	
	8 km										**10 km**									
5—10	4	0																		
10—15																				
15—25									75											
25—40									25											
RANGPUR																				
	4 km.										**6 km**									
5—10	23	0						4	9		7	0								
10—15									22	4									43	
15—25									52										57	
25—40									9											
TEZPUR.																				
	4 km.										**6 km.**									
5—10	12	8		8							4	0								
10—15								8	25										25	
15—25									50									25	50	

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
CALCUTTA.																				
	4 km										6 km.									
5—10	271	10	1	1				5	20	11	192	3	1	1				1	8	3
10—15		.						5	19	9			1					4	19	6
15—25		.						1	10	7								8	37	5
25—40																		1	3	2
	8 km.										10 km.									
5—10	44	0		2					2	5	8	13							13	
10—15									5	7							..			13
15—25				.				16	34	9								13	25	13
25—40								5	14				13							.
>40								2												.
DACCA.																				
	4 km.										6 km.									
5—10	104	3						7	12	2	47	2								
10—15								5	24	4								4	21	
15—25								6	25	6								13	32	6
25—40									3	5							..	4	13	2
	8 km.										10 km									
5—10	6	0												..						
10—15														..						
15—25									17											
25—40								33	50											
CHITTAGONG.																				
	4 km.										6 km.									
5—10	81	12	1					10	15	1	33	0							12	9
10—15								6	25	5								3	27	
15—25									16	7								3	36	6
25—40																				3
	8 km.										10 km.									
5—10	6	0							17		3	0								
10—15					.			17	50							..				.
15—25	.					.	.									.	..	33	67	.
25—40						..			17	.								.	..	.
AKYAB.																				
	4 km.										6 km.									
5—10	304	24	1	..	.		1	7	21	15	241	5	1	..	..	..	..	5	14	4
10—15	.		.	..	.		1	3	14	7	.	.	1	..	..	..	..	8	20	10
15—25	.	..	.	..	.	.	.	1	4	.		.	.	.	..	.	..	1	22	4
25—40			.	..	.						..	.			.		.	..	2	..
	8 km.										10 km.									
5—10	112	4	1			.	2		2		46	2					.	2	7	..
10—15		.				.		5	8	2			.					2	4	2
15—25								13	43	6								9	26	.
25—40								4	11						.			4	33	2
>40																		2	2	2

n represents the total no of observations,

and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

MANDALAY.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	99	8					.	6	25	2	51	0		12	2				.	..
10—15	.		.	.				5	30	3			12	25	4		.	..	.	..
15—25			.		.		.	1	16	3			12	25	8				..	..
	8 km.										10 km.									
5—10	3	0				..												.	.	..
10—15		.							.							..		.		..
15—25								67	.									..		..
25—40										33						..		.	..	..

RANGOON.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	58	57	2	3	2	2	2	7	7	14	43	47	2	2	5	2	5	2	9	9
10—15			2				2		2				5			2	2			2
15—25																			2	2
	8 km.										10 km.									
5—10	6	33				17		33			1		.					100		..
10—15					17														.	..

JUBBULPORE.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	93	14	2					3	17	12	58	5						9	3	2
10—15			1				1	2	17	10			2					7	19	3
15—25									15	5								5	36	5
25—40																			3	.
	8 km										10 km.									
5—10	13	0						8			6	0							17	..
10—15			.						8											..
15—25			.					15	39									17	17	..
25—40	.							8	23									17	33	..

RANCHI.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	17	12		.				6	29	.	4	0						.	25	..
10—15	.	.		.		.			47										25	..
15—25		.				.				6									50	..

SAMBALPUR

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
	4 km.										6 km.									
5—10	36	17	3	.	..		3		19	14	23	9	.	..			4	9	9	..
10—15	.		3	.				6	11	14				.		.	..	.	22	22
15—25	.	.	..				.		8	3			.						17	9
	8 km.										10 km.									
5—10	16	6	..	..	..	.		6			9	0	..	..	.	..	..	..	11	..
10—15	..	.	.	..	..		..	6	25	.	.	.	..	..	..	.	..	.	67	..
15—25	..	..	..	..	..	.		6	44	6		.	.	.	.		.	..	22	..

n represents the total no. of observations

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

Speed limits m/s.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
POONA.																				
	4 km.										**6 km.**									
5—10	202	43	4	3	2	1	4	4	10	7	177	27	3	1	..	1	4	5	11	6
10—15	..	..	1	1	..	..	..	4	8	2	.	..	2		..	1	1	6	12	6
15—25	..	..	..	..	..	..	.	1	4	..		..	.		..	..	..	1	12	2
25—40	.	..	.	..	..	..	..	.	..	..		.	.	.	..	..	..	..	1	1
	8 km.										**10 km.**									
5—10	112	4	1		.		2	6	7	9	47	0	.	..	.	..	..	4	2	..
10—15	..	..	..		.			8	11	5		.	..	.			..	2	19	6
15—25	.	..	..	..	.	.	1	9	24	7		..	..	.			..	4	40	4
25—40	..	.	..	..	..	..	..	1	3	2	.	..	..	.	.		..	2	13	2
HYDERABAD.																				
	4 km.										**6 km.**									
5—10	77	51	7	8	8	3	1	4	1	10	65	42	8		2		2	3	9	12
10—15	.	..	1	.		.	.	.	3	1	.	..	2	.	2	3	..	..	11	3
15—25	.	..	1	..		.	.		1	.		.	..	.	..	..	..	..	2	2
	8 km.										**10 km.**									
5—10	44	25		.	..	..	.	18	16	11	20	0	..	5	.	.	..	15	15	..
10—15	.	..	2	..	.	..	2	2	11	2	.					.	..	20	10	..
15—25	.	..	2	.					5	2	.		.			.	.	15	15	..
25—40	.	.	..	..	..	.	.	.	.			.	..	..	..	..	..	5	..	..
WALTAIR.																				
	4 km.										**6 km.**									
5—10	105	51	5	10	3	3	2	7	7	8	76	26	7	3	1	..	1	12	12	9
10—15	..	..	1	.	..	..	..	3	2	..	.	..	3	3	1	1	1	3	9	4
15—25	.	..	..	..	..	..	..	..	..	..	.	..	1	..	.	..	..	..	..	3
	8 km.										**10 km.**									
5—10	19	32	..	..	..	5	..	11	11	5	5	20	..	.	.	.	..	40	..	20
10—15	..	..	.	..	..	..	..	16	11	5	..	..	..	.	.	..	..	..	20	..
15—25	..	..	.	..	..	..	..	..	5	.	.		..	..	..	..	..	..	..	..
MANGALORE.																				
	4 km.										**6 km.**									
5—10	75	39	1	8	25	7	1	..	..	3	32	34	13	3	13	3	3	..	..	6
10—15	..		..	5	7	1	..	..	.		.	..	..	9	9	.	..	3	..	..
15—25	.	.	..	1	1	.	..	..	..	..		..	..		3	..	..	..	..	..
	8 km.										**10 km.**									
5—10	10	20	..	..	20	20	..	..	10	..	1	100	..	..	..	..	..	..	..	..
10—15	..	..	.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
15—25	..	..	20	..	..	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..

n represents the total no. of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

PERCENTAGE FREQUENCIES OF UPPER WINDS at 4, 6, 8 and 10 km. in DECEMBER.

Speed limits m's.	n	C	N	NE	E	SE	S	SW	W	NW	n	C	N	NE	E	SE	S	SW	W	NW
BANGALORE.																				
	4 km.										6 km.									
5—10	281	49	2	8	17	5	1	..	4	5	216	36	6	6	9	7	2	5	7	2
10—15	.	..	..	1	6	1		.	.				1	4	5	3	..	..	1	1
15—25	.	.	.	.	5										2	.		..	..	..
	8 km.										10 km.									
5—10	140	34	4	1	1	6	4	7	6	6	71	21	1			1	11	11	7	1
10—15	..		3	2	1	2	1	2	7	2			3			3	1	15	4	3
15—25				2	1		1	2	1	1			1	..	1	..	..	3	3	7
25—40			1			.											.	..	.	..
MADRAS																				
	4 km.										6 km.									
5—10	109	55	1	8	15	2	1	1	4	6	80	45	3	5	16	3	4	7	1	3
10—15					6	1		1					.	3	4	3	1	1	1	1
15—25		.																	.	..
	8 km										10 km.									
5—10	39	46	5		5	3	10		10	3	19	26				5		21	16	..
10—15								8	3	3							11			..
15—25								5										16	.	5
PORT BLAIR.																				
	4 km.										6 km.									
5—10	75	58		16	17	5	3				55	42		15	20	7		.	2	..
10—15				1										4	4	4			.	..
15—25														2	2					..
	8 km.										10 km.									
5—10	23	35	9	17	4	9	4		4		8	37		13			.	.	25	13
10—15				4		4									13				..	..
15—25					9														..	..
TRIVANDRUM																				
	4 km.										6 km.									
5—10	65	32		12	18	8	2	2	2	2	40	20	3	7	15	10	.	..	..	..
10—15				5	12	2		2					3	7	20	7	..	..	3	[illegible]
15—25				3									.		3		..	..	..	[illegible]
	8 km.										10 km.									
5—10	9	0	.		22						4	0	.		25	.	..	..	..	.
10—15			.	22	22	11		.		.	.		.	.	50		..	..	.	..
15—25	..		.		22	.	.	.	..				..		25	..	..	..	..	..

n represents the total no of observations,
and C represents the percentage number of cases when speed was less than 5 m/s.

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The Thermal Structure of the Upper Air over a Depression during the Indian South-West Monsoon

BY

N. K. SUR.

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THE THERMAL STRUCTURE OF THE UPPER AIR OVER A DEPRESSION DURING THE INDIAN SOUTH-WEST MONSOON

BY

N. K. SUR.

(*Received on 26th November 1934*)

Abstract.—A depression developed in the Bay of Bengal in the first week of September 1932 and passed through Orissa, the Central Provinces and Central India. From sounding balloon ascents at Agra during the week, it is found that temperature at upper levels below the tropopause at first decreased on successive days as the depression increased in intensity and approached Agra. When the depression deepened further and became practically stationary in the neighbourhood of Agra, an exception is noticeable at the levels between 8—12 gkms., where no fall of temperature occurred. At this stage the level of the tropopause above the depression was lowered with an increase of temperature in the lower stratosphere and a decrease at levels immediately below the tropopause.

1

In a recent communication,[1] the thermal characteristics of the upper levels of the troposphere and the lower levels of the stratosphere over Agra (Lat. 27°08′N, Long. 78°01′E) in the last week of August 1929, when affected by a depression in its neighbourhood have been discussed. It was found that temperatures at all heights up to about 15 gkm. were lower than the normal temperatures prevailing at the corresponding heights in August, and the tropopause was lowered to 15·2 gkms., its mean level in the month lying between 16—17 gkm. As the fall of the temperature below the tropopause was not enough to offset the effect of a lower tropopause, the temperatures in the lower stratosphere between 16—18 gkm. were found higher than the normal. These results were deduced from data obtained from two soundings at Agra on two consecutive days. On the first of these days the depression was at its maximum intensity with its centre at Kotah (Lat. 25°10′N, Long. 75°52′E) at a distance of about 185 miles to the southwest of Agra, but on the next day its intensity was declining. The depression discussed there originated in the Bay of Bengal and was preceded by a wave of low pressure passing westwards through Burma.

It is known that the strength of the southwest monsoon current over northwest India generally diminishes in September compared to that in August, though there may be an exception in any particular year. The depressions forming in the Bay of Bengal in this month invigorate the monsoon current over upper India, if these travel in a northwesterly direction through the central regions of India. Signs of formation of a depression were noticed on the morning of 2nd September 1932 off the Orissa-Ganjam coast in the Bay of Bengal. It developed and crossed the coast near Puri (Lat. 19°48′N, Long. 85°52′E) on the next morning. On the morning of 4th September it lay as an area of shallow low-pressure on the ground with centre near Sambalpur (Lat.

[1] N. K. Sur.—The Distribution of Temperature in the Upper Levels of a Depression originating in the Bay of Bengal during the Indian South-west Monsoon, India Met. Dept. Scientific Notes, Vol. VI, No. 62.

21°28′N, Long. 84° 01′E) in Orissa. By the morning of 5th September it intensified on the ground and lay over the Central Provinces strengthening the monsoon current there The monsoon was also active in Bihar, Orissa and Burma The centre of the depression lay near Guna (Lat 24° 40′N, Long 77 20′E) in west Central India on the morning of 6th September It had intensified further and the monsoon was strong in the central parts of India and active in the northeast of India Though on the morning of 7th September, the depression was found to be practically stationary near Guna, it had further deepened as shown by the fall of pressure on the ground in the morning-chart The monsoon was strong from Gujarat to the west United Provinces and the east Punjab, and generally active in the east United Provinces and Chota Nagpur On the morning of 8th September, the depression was found to have weakened slightly and its central region of lowest pressure was probably spread over a smaller area on the ground as compared to that on the previous morning, as far as it can be inferred from the surface charts It had moved in a northeasterly direction and its centre lay over Nowgong (Lat 25 03′N, Long 79°30′E) in Central India. It continued to diminish in intensity during its movement towards west United Provinces through the southern divisions of the province and after persisting over the neighbourhood of Mainpuri (Lat 27 14′N, Long 79 03′E) for a couple of days disappeared by the morning of the 13th

The central region of the depression was at a distance of about 300 miles from Agra on the morning (8 A M) of 5th September, while on 6th, 7th and 8th September the distances of the centre were about 210, 180 and 170 miles respectively from Agra. The weather conditions on 5th, 6th and 7th September are shown in the corresponding surface charts (See *figs 1, 2* and *3*) In these charts the isobars, directions of winds, places of rainfall at 8 hrs (by shaded areas) and rainfall during the last 24 hours in inches have only been shown

The time of letting off the meteorographs at Agra, the distance and direction of place of recovery are shown in *Table I*

TABLE I

Date	Time I S T	Place of recovery	Distance in miles	Direction in degrees from N-S line through Agra
3 9 32	1724	Kiraoli Dist , Agra	15	216°
5 9.32	1715	Bharatpur	33	273°
6 9 32	1720	Muttra Dist	30	316°
7 9 32	1725	Muttra Dist	37	329°

The data for temperature and pressure obtained from the records of the meteorographs are given in *Table II*, in which the normal values over Agra for both August and September are also shown for facility of comparison As the depression was near Agra in the first week of September, the *mean* of the normal values for each height for the two months would probably be a better standard of comparison than the normal values for September only The number of observations for both the months varies between 34 and 30 from ground to 7 gkm levels, between 27 and 20 from 8 to 14 gkm. levels, and between 20 and 13 from 15 to 18 gkm. levels.

TABLE II.

Gkm.	Temp (°A) and Press. (mb).				Normal Temp. (°A) and Press (mb).	
	3.9 32.	5.9 32.	6.9 32	7 9 32.	August	September.
0·17 (surface)	306·5 976	303·0 978	303·0 974	301·0 974	303 981	304 983
0·5	 .	301·5 943	299·5 937	299·0 939		.. .
1	298·5 888	297·0 889	294·5 885	295·5 885	297 891	299 894
1·5	293·5 837	294·0 839	291·0 834	293·0 835	.	.
2	291·0 788	291·5 791	289·0 786	291·0 787	291 792	291 794
3	286·5 700	286·0 703	285·0 697	286·5 699	285 702	285 704
4	282·5 619	281·5 621	280·5 617	282·5 618	281 622	280 622
5	277·0 546	275·0 548	274·0 544	277·5 546	276 549	274 550
6	273·0 481	270·0 483	268·5 478	272·0 481	272 483	270 484
7	266·5 423	264·5 424	263·0 420	267·0 423	266 424	264 424
8	261·0 371	258·0 371	259·0 368		260 372	258 371
9	252·5 324	251·0 324	251·5 321		252 325	250 324
10	246·0 282	243·5 282	244·0 278		246 282	243 281
11	238·5 244	235·5 244	235·0 241	.	237 244	236 243
12	230·0 211	224·5 209	225·5 207		229 211	227 209
13	221·5 181	217·0 178	216·0 177	. ..	220 180	218 179
14	213·5 154	208·0 152	205·5 150	.. ..	211 153	208 152

TABLE II—*contd.*

Gkm.	Temp (°A) and Press (mb)				Normal Temp (°A) and Press. (mb).	
	3.9 32.	5 9 32	6.9.32.	7 9 32	August	September.
15	204·0 130	199·0 128	195·0 127		202 129	201 128
16	195·5 109	193·0 107	193·5 106		195 108	195 107
17	193·0 91	189·5 89	195·0 88		193 90	193 89
18	194·5 76	.	199·0 74		197 76	199 75

2

As the depression was at a considerable distance from Agra on the evening of 3rd September (between Puri and Sambalpur), the atmosphere over Agra could but be affected very little by it, though cirrus clouds of amount 10 (Ci_{10}) were present over Agra in the morning of that date. At the time of ascent of the meteorograph in the evening only Cu_2 clouds were noticeable With further intensification of the depression and its movement towards Agra, it may be expected that in the evening of 5th September the upper air over Agra was under its influence, however weak it may be, as the distance of its central area of low pressure was about 250 miles from Agra. On 5th September Ci st, A cu and Cu nb were present over Agra in varying amounts throughout the day, Ast also appearing at 16 hours I. S. T. At the time of ascent, Ci_2 (A cu and St cu)$_?$ were observed, lightning being also noticed at a distance within three hours of the ascent Apart from the marked decrease of temperature on 5th September on the ground compared to that on 3rd September[1] a fall of 1°·5 A was also recorded at 1 gkm. level. The temperatures at 2 and 3 gkm levels were nearly the same on both the dates, but the temperature diminished progressively upwards from 3 gkm level Between 12– 15 gkms it fell by 5°, though at 16 and 17 gkms. it was less by about 3° only.

The level of tropopause on 3rd September was at 16 22 gkm (press 105 mb., temp. 194°A, potential temp. 372°) As the meteorograph did not penetrate levels above 17 km., there is considerable uncertainty in ascertaining the level of tropopause on 5th September. It may be fixed at about 16 05 gkm, temperature 190°·5 ; but above this level temperature was still falling slightly, being 189°·5 at 17 km.

The height-temperature diagrams for the ascents on 3rd, 5th, 6th and 7th September are given in *Figs. 4 a* and *4 b*. Attention is here drawn to the portion of the curve for 5th September between 14·90 and 15·63 gkm where its trend is disturbed, howing a decrease in the vertical lapse-rate of temperature.

[1] No rainfall was recorded at Agra between the evenings of 3rd and 5th September, though there was rain in surrounding places, *e g.*, Allahabad, Benares, Lucknow and Jhansi. In the early morning of 6th September there was drizzle at Agra. Cooler air had apparently come over Agra by the evening of 5th September. The cooling at the lowest layers may have been caused to some extent by the flowing of easterly rain-cooled air of the adjoining country.

The depression considerably intensified by the morning of 6th September and deepened a little more by the next morning, its central region with the lowest pressure lay between 210- 180 miles to the south of Agra. The meteorograph let off on the evening of 6th September[1] may be expected to have traversed at least the outer regions of the upper air affected by the depression, as the pressure at all heights, from ground to 18 gkms., as seen from *Table II*, were lower than those at the corresponding levels on 5th September the fall varying from 4 mbs at ground to 1 mb at levels near the tropopause On 6th September there was a further fall in temperature of 2°·5 at 1 and 2 gkm compared to those on the 5th September From 3—7 gkms it was of the order of 1 only. But from 8- 12 gkms, though the change in temperature was not marked, there was no fall[2].

At 13, 14 and 15 gkm. levels a decrease in temperature by 1°, 2°·5 and 4° respectively was recorded, but it increased by 4°·5 at 17 gkm compared to those for the same levels on 5th September.

On the evening of 7th September, the depression was apparently weakening as shown by the higher pressures above 2 gkm Except on the ground where a further decrease[3] of 2 was recorded, the temperatures for all heights upto 7 gkm. were higher than those on 6th September

On 6th September an isothermal region existed between the heights of 15150 and 16040 geodynamic metres followed by a weak inversion up to about 17 gkms. after which the intensity of the inversion increased The tropopause was at 15 15 gkm [4], the levels of tropopause on 3rd September and 5th September being at 16 22 and 16 35 gkms. respectively

The lowering of the tropopause with the distribution of temperature just below and above the tropopause on 6th September is remarkable.

In *Table III* are given equivalent potential temperatures for levels, upto 6 gkms. only for 3rd, 5th, 6th and 7th September.

---

[1]The weather conditions at Agra on 6th September 1932 were as follows: From early morning to 08 18 hrs I S T. the sky was overcast with St and Cu nb clouds, accompanied with drizzling at intervals At mid-day A cu and Ci st were observed along with Cu and Cu nb Rain at 18 07 and 19 30 hrs from Nb clouds was followed later by showers at intervals with occasional thunder and lightning The sky was overcast with low clouds at the time of ascent.

[2]Attention is here drawn to the distribution of temperature of 26th August 1929 and 27th August 1929 over a depression near Agra (*vide* N K Sur *loc cit Table I*) It is note-worthy that the temperatures from 5 to 9 gkm levels were not lower but slightly higher on 26th than those for the same levels on 27th when the depression was weaker than on 26th

[3]This cooling may have been very largely produced by rain falling on 6th and 7th September.

[4]The normal height of the tropopause over Agra in September lies between 16 and 16·5 gkms. Compare with the level of tropopause on 26th August 1929. See N. K. Sur, *loc. cit.*

TABLE III.

Equivalent Potential Temperature and Relative Humidity.

Gkm	3 9 32		5 9 32		6 9 32		7.9.32.	
	°C	R H %	°C	R H %	°C	R H %	°C	R.H. %
0 17	78	52	85	78	86	80	78	80
0 5				.	81	85	78	83
1	78	73	76	79	73	91	78	86
1 5	77	91	79	92	71	96	73	84
2	75	90	75	85	72	98	73	83
3	66	58	75	92	73	97	73	82
4	65	32	74	85	71	84	75	48
5	66	19	73	96	71	98	76	79
6	71	18	74	100	71	100	77	83

The higher equivalent potential temperatures from 3 to 6 gkms on 5th September compared to those for the same levels on 3rd September are significant, for though the temperatures at these levels decreased on 5th September humidity increased markedly and the air had greater heat-content. Another noteworthy result is that on 6th September, when the depression deepened, the E. P. temperatures decreased slightly from 1 to 6 gkm. levels. The temperatures at these levels decreased in comparison to those on 5th September, but humidity increased slightly from 1 to 5 gkms. The E P temperatures *on ground* on these two dates were practically equal, and there the temperatures also were equal.

On 7th September, the decrease of temperature on ground and at 1 gkm. was accompanied with a fall of E. P. temperature also, but in the higher levels these increased except at 2 and 3 gkms , where these were the same as on the preceding day.

The E. P. temperature at 1 gkm. on 7th September is greater than the corresponding one on 5th September, though the temperature at 1 gkm. on 7th September was less than that on 5th September for the same level.

3

The data presented in this note agree in the main with those in the previous communication. A tropopause at a lower level with a characteristic isothermal region has been found to exist over both the depressions. when near Agra.

The lowering of the tropopause accompanied with an increase of temperature in the lower stratosphere and the associated isothermal region can be explained as due to the sucking down of air of the lower stratosphere and the divergence of air of the troposphere just below the tropopause, which is usually pictured to take place in the higher levels of a depression near the tropopause.[1] The downward motion of air of the lower stratosphere is accompanied with heating, as is shown by the higher temperatures on 6th September just above the tropopause at 17 and 18 gkm. levels.

[1] See A. Refsdal, Zur Thermodynamik der Atmospahre, Geofysiske Publikasjoner, Vol. IX, No. 12, fig. 12, p. 55, 1932.

The upward motion of air over a depression causes a fall of temperature just below the isothermal region as shown by the temperatures at 13, 14, and 15 gkm levels on the same date as compared to those on 5th September The isothermal region may be due to the heating caused by the divergence of air, which is accompanied with an increase of cross-section [1]

Not a fall but *perhaps* a very slight increase of temperature at 8 12 gkms (excepting at 11 gkm.) was recorded on 6th September as compared to those at the corresponding heights on 5th September The depression had intensified more on 6th September As mentioned before slightly higher temperatures from 5 to 9 gkms. on 26th August 1929, when the depression was more deep than on the succeeding days had been noticed This is no doubt partly due to the presence of middle and high clouds, but it may point to another feature It probably also indicates the lifting up of the warmer air mass of the depression to a higher level, when it had deepened.

4

The present state of our knowledge of depressions of the Indian southwest monsoon season can only lead to conjectures regarding the physical processes going on in such a depression The depressions of the monsoon season in India are not symmetrical with reference to their centres as is shown by the distribution of rainfall in the different sectors of a depression, but little is known regarding the distribution of temperature in the upper air above the different sectors The two masses of air responsible for the birth of a depression in the Bay of Bengal the southwesterly and easterly streams of the monsoon, flow in opposite direction and the gradient of temperature in horizontal levels of the upper air is from north to south, the easterly branch being somewhat warmer than the southwesterly, as can be inferred from the normal temperatures at different heights of the troposphere obtained from sounding balloon ascents at Agra (Lat 27° 08′N Long 78° 01′E) and Poona (Lat 18° 32′N, Long 73°51′E) This gradient of temperature being opposite to that usually prevailing in an extra-tropical cyclone, the monsoon depressions move in an opposite direction to that of the latter, *i e*, towards west These depressions have a few features of asymmetry similar in some respects to that of an extra-tropical cyclone, and it is not altogether improbable that the fall of temperature, as well as the slight decrease in heat-content of air at 1– 6 gkm levels, accompanied perhaps with the lifting up of warm air upto 12 gkms on 6th September indicates a phenomenon analogous to the occlusion of an extra-tropical cyclone

The equality of temperatures, and E P temperatures on 5th and 6th September on the ground does not necessarily go against the above idea For the E P temperature on 6th September began to decrease soon after the ascent of the meteorograph as shown below –

TABLE IV

Date	Hrs (I S T)	0800	1200	1400	1530	1600	1700	1800	1900
5 9 32	E. P. T. (°C)	78	82	85	82	82	85	83	82
Date.	Hrs (I S. T)	1700	1730	1810	1900	1930	2200		
6 9 32	E P T. (°C)	85	85	79	79	79	75		
Date	Hrs (I S T)	0200	0800	1200	1400	1520	1640	1725	
7 9 32	E P T (°C)	75	75	81	85	80	74	78	

[1] *Vide* N. K. Sur *loc cit.* Compare also the distribution of temperatures on 26.8.29 at 16, 17 and 18 gkms. for rise of temperature and at 12, 13, 14 and 15 gkms. levels for decrease below the isothermal region extending from 15·21 to 15 71 gkms.

The values have been computed from a dry and wet bulb thermograph at the Agra Observatory. It showed a sudden decrease of temperature of about 5°·5F and 2° F in the records of the dry and wet bulb respectively at 1810 hours I S.T.; lightning being also noticed in the neighbourhood of Agra. A squall of a short duration commencing at 1800 hrs. and lasting for 8 minutes only is also noticeable on the Dines P. T anemogram for 6th September The speed of wind during the squall increased from 8 miles to 20 miles per hour, after which it again fell to 9 miles per hour. The direction of wind previous to its onset was from NE, but changed to SE, while it lasted, and again assumed the NE direction after it was over. It continuously changed from NE to ESE[1] from about 2100 hours I. S T. on 6th September to 0900 hrs I S. T on 7th September. A rainfall of 0·38″ during the squall was recorded by a self-recording raingauge at Agra. These phenomena associated with a lower[2] E P temperature after 1810 hrs. show that a different mass of air spread over Agra after 1800 hrs I S T on 6th September.

It is believed that the cold air behind the cold front of an extra-tropical cyclone can generally sink as a whole in its later stage of development and spread on the ground and thus lead to occlusion of the cyclone The squall at 1800 hrs I S T, associated with rainfall, and fall of temperature and E P temperature, and the continuance of a lower temperature till the evening of 7th September show that probably the cold air descended at that instant, and that afterwards it spread on the ground. Though the available data in the present case are insufficient to permit a detailed study of the phenomenon the above tentative suggestion has been put forward to be further developed or modified as more complete information become available.

The depression of 26th and 27th August 1929 discussed in the previous note developed in the Bay with the passage of a low pressure wave through Burma, but the present one formed in the Bay without being preceded by such a wave. Both have shown similar distribution of temperature in the neighbourhood of the tropopause, above and below it, and its level over Agra, when the depressions were near the place, was lowered simultaneously with their deepening. If these features are associated with the deepening of a depression in its later stage of development, it can be expected that these characteristics will not be found over a depression freshly formed in the Bay of Bengal during the monsoon.

My thanks are due to Messrs Ram Sahay, Brij Mohan and Vidya Bhushan of the Agra Observatory for help in computation and preparing the diagrams, and to Mr G Chatterjee, Meteorologist-in-charge for placing the sounding balloon data at my disposal

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[1]The direction of ground wind at 8 hrs. on 6th September 1932 was ENE, and at 8 hrs. on 7th September 1932 was E

[2]The increase at 12 and 14 hrs I S T on 7th September 1932 is evidently due to insolation The fall after 18 hrs I S T on 6th September is not due to the approach of night, as shown by a comparison with the values of E P. T at 1800 and 1900 hours on 5th September.

[3]See Physikalische Hydrodynamik by V. Bjerknes, J. Bjerknes, Solberg, and Bergeron 1933, pp. 517 and 718.

M50DGofOb.—23-8-35—380—GIPS

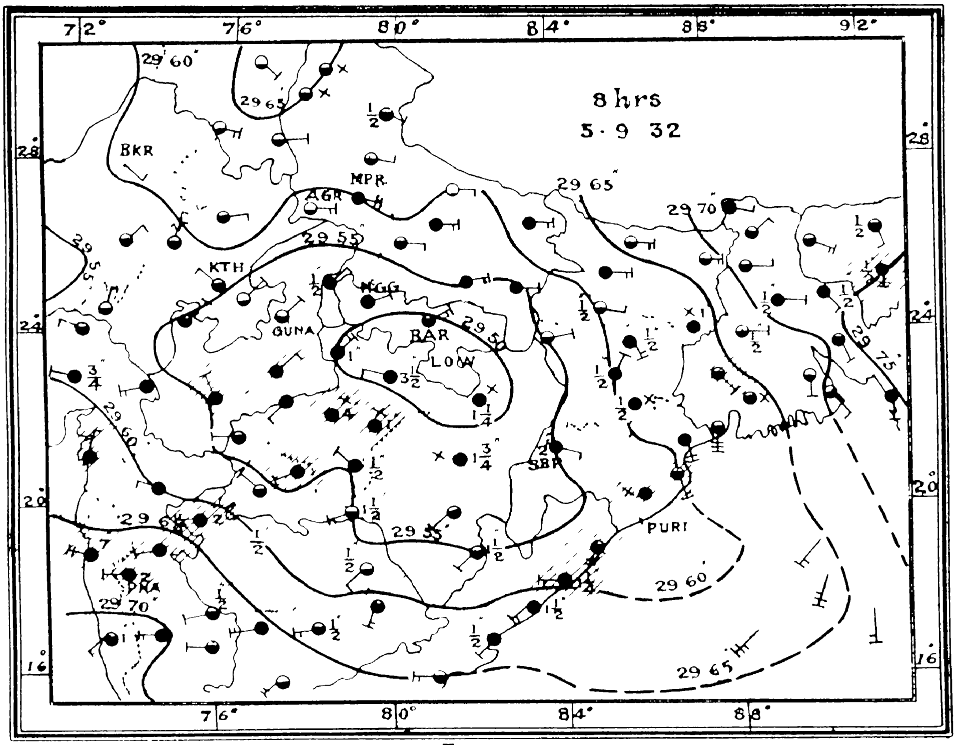
8 hrs
5 · 9 32
72°
76°
80°
84°
88°
92°
28°
24°
20°
16°
BKR
MPR
AGR
KTH
NGG
GUNA
BAR
LOW
SBP
PURI
PNA
29·60″
29·65
29·55″
29·50
29·65″
29·70″
29·75
29·60
29·70″
29·65

Fig. 1

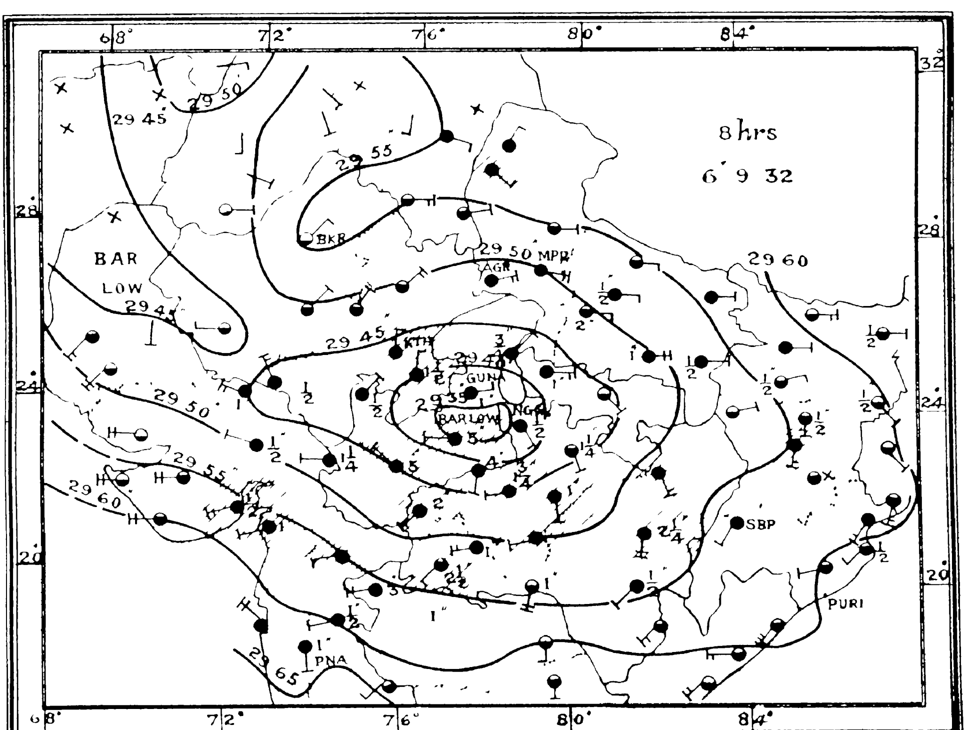
8 hrs
6 9 32
68°
72°
76°
80°
84°
32°
28°
24°
20°
BAR
LOW
BKR
AGR
MPR
KTH
GUNA
NGG
BAR LOW
SBP
PURI
PNA
29·50
29·45
29·55
29·45
29·50 MPR
29·60
29·45
29·40
29·35
29·50
29·55
29·60
29·65

Fig 2

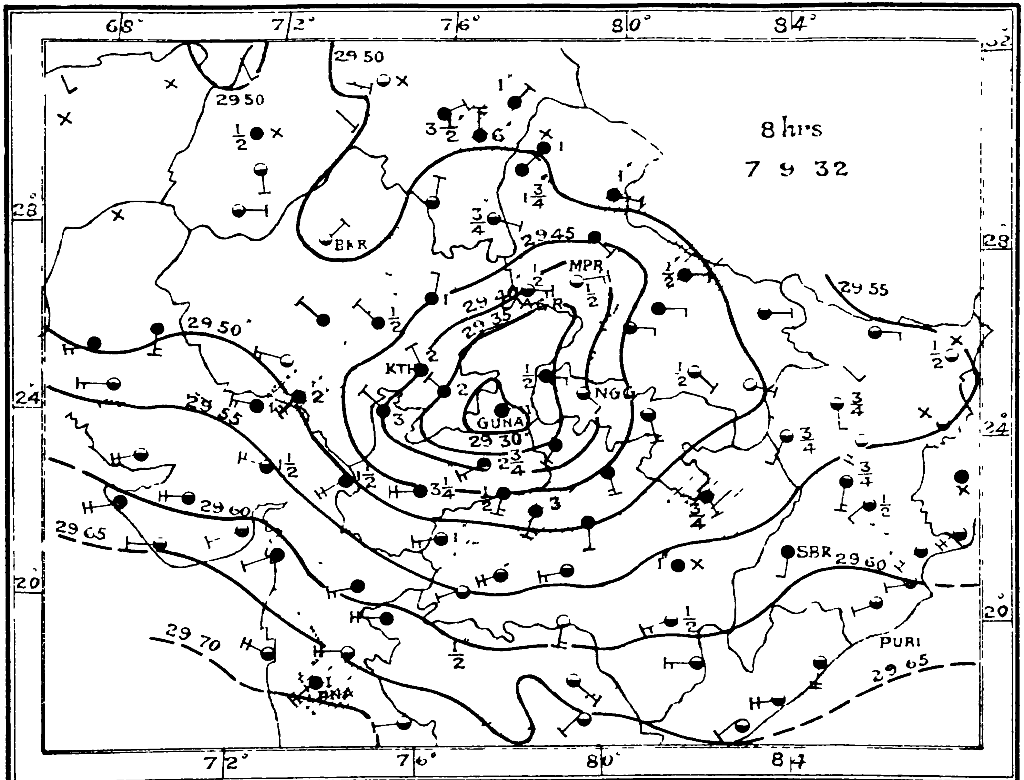
8 hrs
7 9 32
29 50
29 45
29 40
29 35
29 30
29 55
29 60
29 65
29 70
MPR
AGR
KTH
GUNA
NGG
BKR
SBR
PURI
68°
72°
76°
80°
84°
28°
24°
20°

Fig 3

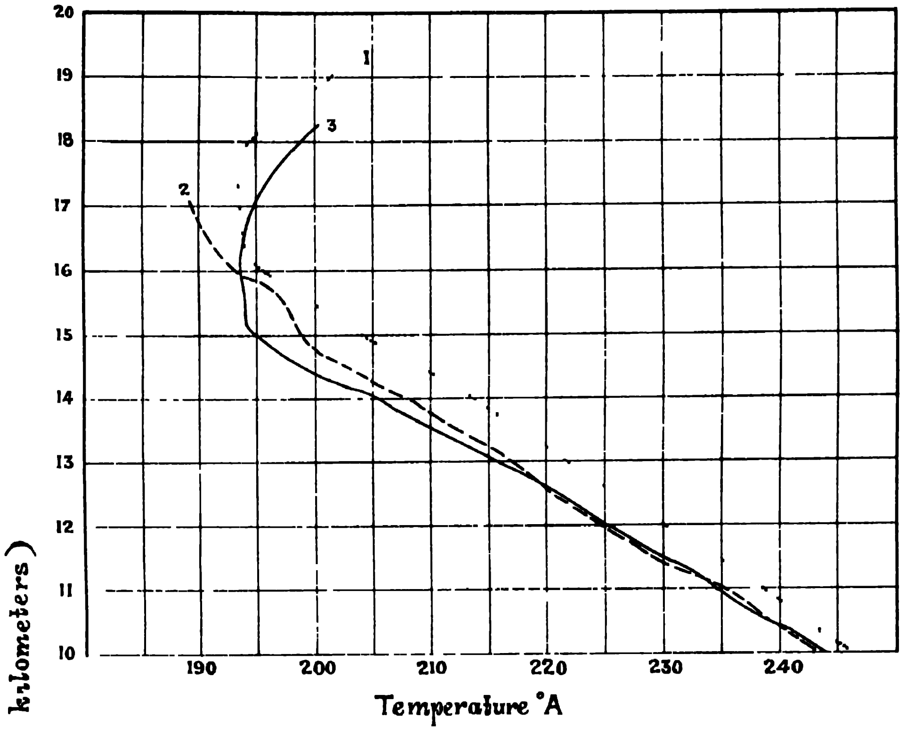
Heights (geodynamic kilometers)
Temperature °A
1
2
3

Fig 4 a

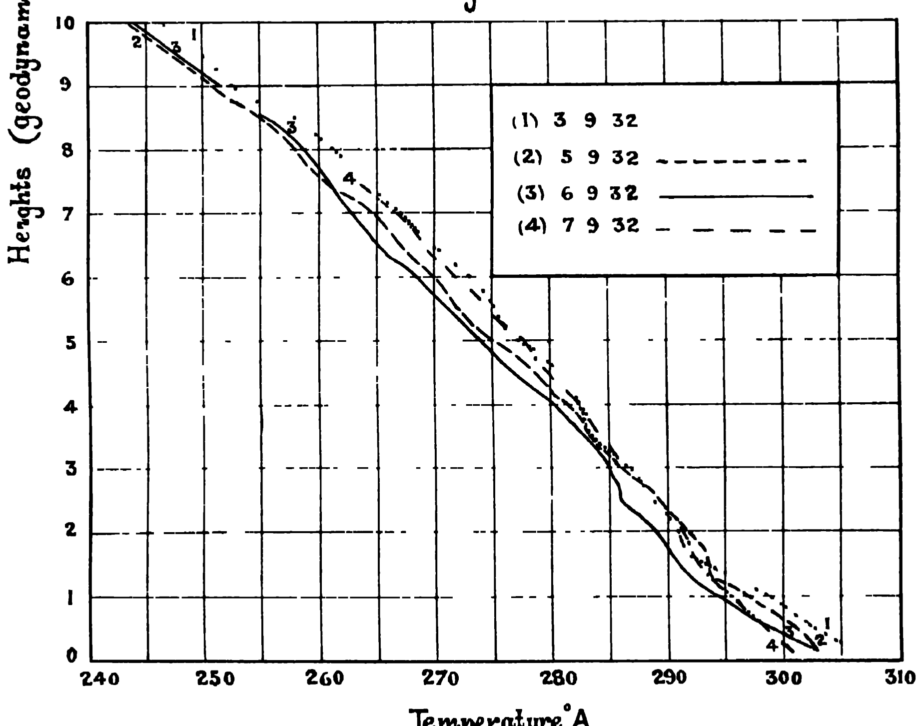
Temperature °A
(1) 3 9 32
(2) 5 9 32
(3) 6 9 32
(4) 7 9 32
1
2
3
4

Fig 4 b

NO-SN6/64

INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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Some Observations on the Thermal Structure of Cumuliform Cloud

BY

FLT.-LIEUT. R. G. VERYARD, B.Sc., R.A.F.

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SOME OBSERVATIONS ON THE THERMAL STRUCTURE OF CUMULIFORM CLOUD.

BY

FLT.-LIEUT. R. G. VERYARD, B.Sc., R.A.F.

(*Received on 31st October 1934.*)

Summary.—During 1932 and 1933 a number of observations were made at PESHAWAR, KOHAT and RISALPUR, in the N.-W. F. P., of the temperatures (dry and wet bulb) inside and outside cumulus and cumuliform clouds. Although the readings cannot be accepted as reliable to within less than 1° F., they are interesting inasmuch as they confirm that the temperature inside cumuliform cloud may be higher or lower than the temperature of the surrounding air. An analysis of the results shows that (*a*) on thirteen out of the fourteen occasions when the cloud was observed to be dissolving, its temperature was mainly lower than that of the surrounding air, and (*b*) out of twenty occasions when the cloud was observed to be growing, its temperature was mainly higher than that of the surrounding air on ten occasions but mainly lower on six occasions. With regard to the question of supersaturation, the observations do not show convincingly that supersaturation occurs in cumuliform cloud.

Whilst the author was on a visit to the Headquarters of the India Meteorological Department early in 1931 he was asked by Dr. C. W. B. Normand, M.A., D.Sc., the Director General of Observatories to make arrangements with the Royal Air Force to take, if possible, some observations of temperatures inside and outside cumulus clouds in order to ascertain whether such observations would verify the results obtained by W. Kopp and others ([1] to [5]). Kopp had observed that a fall of temperature occurred on entering cumulus clouds, the fall being greatest near the top of such clouds but comparatively small near the base. In order to account for the buoyancy of the cloud, Kopp put forward the theory ([1]) that supersaturation up to 300% or more occurs inside the cloud and actually quotes one case of supersaturation amounting to 600%. Certainly, one might deduce such supersaturation to occur by assuming, for a cloud in the steady state, the density inside and outside to be the same. If, however, there is supersaturation in cumulus clouds, the behaviour of a wet bulb thermometer therein would be of great interest. It was considered desirable therefore, to arrange for wet bulb readings to be taken instead of obtaining humidity readings with a hair hygrograph. That is, it was deemed important whenever a change of dry bulb temperature was recorded between the inside and outside of a cloud, to know also the simultaneous variation of the wet bulb temperature.

In the first four papers given in the list of references at the end of this note, all the authors state that with the aid of self-registering instruments, they found the temperature inside cumuliform cloud to be lower than that of the surrounding air, also S. Mal ([6]) in his paper on stratified clouds gives three curves showing a fall of temperature within strato-cumulus and alto-cumulus clouds. W. Wenzel, ([5]) however, obtained one case when the temperature increased on entering the cloud. Nevertheless, Wenzel did not contradict the results of Kopp but stated that the clouds in

which the latter made his observations were probably in a dying stage, whereas in his, Wenzel's, case the cloud was actually in a stage of formation.

F. J. W. Whipple (7) suggested that Kopp's observations might be explained by supposing that, whilst the cloud is actually heavier than the surrounding air, support is provided by the lightness of the ascending column of air below. He pointed out that before the condensation level is reached the rising air may be a little colder than other air at the same level. In this respect the observations made by the author at Thandiani—given as an appendix to this note—are interesting.

C. K. M. Douglas (8) subsequently pointed out that he had already (9) noted the same phenomena as Kopp, and was of the opinion that the warm air rising from a layer near the ground—the lapse rate in this layer exceeding the adiabatic—floats upwards like a bubble*, and, although losing eventually its original vertical velocity, is carried beyond the equilibrium position by its own momentum. If this is correct one would expect rising currents under a developing cumulus cloud, but a downward movement under a dissolving cloud. On most of the days when the clouds were growing pilots *did* report "bumpiness", particularly at levels where the lapse-rate was superadiabatic. On the other hand "bumpiness" was not observed on *every* occasion when the cloud was growing and was sometimes reported on days when the cloud was actually melting. However the "bumpiness" associated with cumulus clouds is not necessarily due to vertical currents; it may be caused by eddy-motion or even by small changes of wind direction or velocity. Moreover, practically all the observations were made over or near hills with the result that "bumps" would be felt on account of irregular movements caused by the uneven contour of the ground.

In a later paper (10) on cloud formation, Douglas states that "in fine weather the air round the clouds is often dry and the effect of the difference of humidity on the buoyancy of the cloud may be sufficient to balance a slightly lower temperature in the cloud ranging up to 1° C. in extreme cases." The observations on 9.9.33 and 23.9.33 support this idea. Appreciable differences of humidity were also recorded when the weather was disturbed, *i.e.*, on 29.3.32, 9.8.32, 28.12.32, 15.2.33 and 23.6.33, although on 9.8.32 the cloud (Cu.Nb) was warmer than its environment, on 29.3.32 and 15.2.33 the bottom of the cloud was warmer but the top colder, than the surrounding air.

It is perhaps appropriate to refer here to the very interesting record obtained by L. H. G. Dines (11) at Kew when a registering balloon, with a meteorograph attached, apparently passed through the centre of a cumuliform cloud. The record indicated exceedingly sudden changes in the lapse-rate of temperature. An important feature was the very rapid fall of temperature—about 5° C. per 100 m.—combined with a sudden fall of relative humidity in the layer of air just above the top of the cumulus cloud. Dines suggests that the relatively dry air above the rising top of the cloud would be borne upwards and thus acquire a temperature lower than that of the saturated air below owing to the difference between the adiabatic lapse rates for saturated and unsaturated air. The dry layer would also be cooler than the undisturbed air at the same level (unless the general lapse-rate equalled the dry adiabatic) and continually slide off the "hump" of the cumulus cloud. No records were obtained having any exact analogy to this case, which was probably abnormal.

With regard to the question of supersaturation a recent article by W. J. Humphreys (12) proves to be rather disconcerting to those who believe in the existence of supersaturation in the atmosphere. Also a paper by Findeisen (13) shows that any considerable supersaturation in clouds is impossible, but a slight supersaturation

* In a recent communication to the author Capt. Douglas says that the structure is too complex to be represented really adequately by a bubble, and that there may be something of the cell structure—of the type investigated by Sir Gilbert Walker.

may occur in rapidly rising currents owing to the cloud particles being a little warmer than the expanding and cooling air. On a number of occasions the reading of the wet bulb was higher than that of the dry bulb by 0.5° to 1.0° F but, in view of the order of accuracy and in the absence of more evidence these readings must be regarded as fortuitous. On the other hand, there were a few instances when the air inside the cloud did not appear to be completely saturated, *e.g.*, on 13.5.33, 16.7.33, 21.7.33 and 17.9.33. In this connection attention is drawn to an article (14) on fog and relative humidity in India in which cases are cited where the percentage humidity was less than 100% in what appeared to be fog.

It seemed at first that it would be a fairly easy matter to obtain readings of dry bulb and wet bulb temperatures in cumulus cloud as suggested by Dr. Normand. The five squadrons attached to No. 1 (Indian) Group Headquarters had regularly carried out daily meteorological flights for many years and the Group Commander (now Air Commodore A. S. Barratt, C. M. G.) readily gave permission for an appeal to be made to pilots to take readings in and near cumulus clouds whenever a suitable opportunity occurred— provided no unnecessary risks were incurred. It should be mentioned that the five squadrons (Nos. 11, and 39 at Risalpur, 27 and 60 at Kohat, and No. 20 at Peshawar) each take their turn for a week at a time in observing upper air temperatures daily up to 15,000, 16,000 ft. above ground level. The heights of Risalpur Peshawar and Kohat aerodromes are respectively 1,050 ft., 1,150 ft., and 1,750 ft., above sea level. The surrounding country is very rugged, and the high mountains (over which cumulus and cumulo-nimbus cloud so frequently forms) more or less follow the line of the frontier across which it is forbidden to fly. As no special flights were permitted, most of the ascents were made in the morning (*i.e.*, during working hours) when cumulus clouds are generally in a stage of development. As a result there were less opportunities for taking observations in clouds that were in a dying stage. In any case, the danger of entering very thick cumuliform cloud over such mountainous country— mostly barren and desolate— within such a short distance of the frontier reduced the chances of taking observations to a minimum. Nevertheless, the appeal to pilots to take readings whenever a reasonable opportunity occurred during a meteorological flight produced a most satisfactory response.

The only recording instruments available were a barothermograph made by the R. A. E. and a Bosch meteorograph. The former instrument possessed no humidity element and too constricted a scale for the object in view. The latter instrument although suitable for the purpose could not be utilised owing to the lack of apparatus for the frequent calibration that would have been necessary and to the want of skilled personnel for working out the results. Hence there was no alternative except to use the ordinary strut psychrometer in daily use without a supplementary recording instrument. When the observations were commenced, in 1931, an instrument with sliding lens (15) was the only type available. This psychrometer had always been unpopular with pilots owing to the difficulty of discerning clearly the top of the mercury columns because of stray reflections, etc., and a request had already been made for the supply of a better type of instrument. On several occasions pilots were quite unable to take readings in cloud owing to the deposition of water on the sliding lens. Also, moisture would collect on the bulbs of the unprotected dry bulb thermometers and thus vitiate the observations. Early in 1932, however, a supply of new strut psychrometers was received—the thermometers of which were made with lens-fronted stems like ordinary clinical thermometers. Each thermometer had been carefully tested and calibrated at the N. P. L. Only readings obtained with these instruments have been included in this paper—the results obtained with the original psychrometer being regarded as unreliable. The observations were discontinued soon after the expiration of the Polar year.

The author gave personal instructions regarding the method of taking the readings during his annual lectures on meteorology. These instructions were subsequently supplemented according to the directions contained in Circular No. 34 (12.7.32) issued by the International Meteorological Committee. The psychrometer was fitted to an outer strut with the wet bulb to the rear or lee-ward side of the dry bulb. Readings were taken at ground level and at every 1,000 ft.—the altimeter being set at zero before taking off. It was left to the discretion of the pilot at what intervals he should take readings inside and outside clouds. As a check on the behaviour of the altimeter, a sensitive aneroid, which had previously been calibrated, was also read at every 1,000 ft. Arrangements were made for the wet bulb to be provided with clean wick and linen at least once a week. Pilots were asked to fly their machines in such a direction as to avoid direct radiation on the psychrometer during the actual time of observation, and to take readings in cloud during the ascent and *not* during the descent. All the observations were made whilst flying horizontally. It will be realised that the time taken by a machine to traverse a cumulus cloud of even large dimensions would be very short. Owing to the comparatively slow action of the strut psychrometer it was necessary to read to the nearest 0·5°F. (by no means an easy matter) and to ensure that the thermometers were "steady".

It will be seen from the results obtained that the differences of temperature actually observed between the inside and the outside of the clouds were all very small. In fact, it is highly probable that the true differences were appreciably greater and the readings cannot be regarded as accurate to within less than 1°F. Only those observations which are considered to be fairly reliable have been given in this paper, and it is regretted that the efforts of many pilots have had to be disregarded chiefly because of their failure to "flatten out" for a sufficient length of time at the level of observation. The author went up himself on several occasions to take the readings and therefore realises how very difficult it was to make precise observations. On one interesting occasion ([16]) the author and his pilot had an attack of hay fever whilst flying in a small cumulus cloud. The observations therein were consequently unreliable!

The data obtained are set out in *Table I*—the readings actually taken inside cloud being given in brackets. The weather conditions for each date on which observations were made, together with brief remarks on the results obtained, are given in the last Column of *Table I*.

It will be noted that the pilots sometimes observed a drop of temperature inside cumulus cloud as noted by Kopp, but at other times a rise of temperature as detected by Wenzel. Omitting the results obtained on 13.2.32 and 23.3.32 when readings were not taken both inside and outside the cloud, it will be seen that, out of 34 sets of observations the cloud was mainly cooler than its environment on 19 occasions and mainly warmer than its environment on 10 occasions. On the five remaining days the cloud had either the same temperature as the surrounding air or was partly warmer and partly cooler. The greatest differences observed were 3·0°F for the dry bulb on 12.7.33 and 5·5°F. for the wet bulb on 9.8.32. Height temperature-humidity curves are given in *Figs. 1* and *2* showing the observations made on 15.2.33 and 12.7.33.

Analysis of the data shows that on 14 occasions the cloud was observed to be dissolving and, except on 15.2.33 the temperature in each case was mainly lower inside the cloud than outside.

On 20 occasions the cloud was observed to be in a state of development; in 10 cases the surrounding air was mainly cooler, and in 6 cases warmer than the cloud

itself; on 1 2 32, 29 3 32, and 25 6 33 the cloud was warmer at the base, but either cooler or the same as outside at the top, on 17 9 33 no difference was observed between the temperatures of the cloud and that of its environment

Of the 34 sets of readings 25 were taken in cumulus cloud, in 7 cases the cloud was mainly warmer and in 14 cases mainly colder than the air outside, on the 4 other occasions the temperature of the cloud was either the same as, or partly higher and partly lower than that of its environment

Readings were taken inside cumulo-nimbus cloud on 6 occasions, in 3 cases the cloud was warmer and in 2 cases slightly cooler than the surrounding air, on 1 day, 1 2 32, the cloud which had a flat summit —was warmer than its environment at the bottom but practically the same at the top

Observations were made in alto-cumulus on one day only, 24 3 32, when the cloud, which was castellated, was slightly cooler at its base and slightly warmer at its top than the air outside

Readings were taken in strato cumulus on three occasions, on each of which the temperature of the cloud was slightly lower than that of the surrounding air

An examination of the lapse-rates of temperature shows that in only one case was an inversion recorded below the cloud, *i e* on 10 7 32 On this occasion the inversion was associated with a change of air-mass In many cases there was a super-adiabatic lapse-rate at some level below the cloud, especially on those occasions when the cloud was growing Regarding the lapse-rate inside the cloud, it will be seen that it was equal to or greater than the saturated adiabatic on 23 out of 30 occasions. With the possible exception of the alto-cumulus cloud, observed on 24 3 32, the lapse-rate in clouds that were in a process of development was equal to or greater than the saturated adiabatic in every case For dissolving clouds the lapse rate therein was less than the saturated adiabatic on four occasions It is feasible that a lapse-rate within the cloud exceeding the saturated adiabatic might be produced when air just above the cloud is first forced upwards whilst still unsaturated and later absorbed into the cloud One may sometimes see 'caps' above growing cumulus absorbed in this way An examination of the lapse-rate at the top and immediately above the clouds indicates that the majority of cases when the clouds, or their tops, were colder than their environment occurred when they projected into an inversion or stable layer.

In conclusion, the author desires to emphasise the fact that these observations cannot be regarded as entirely accurate for reasons already explained, and it is considered inadvisable to arrive at any definite conclusions On some days it was doubtful whether the pilot had reported the right kind of cloud and also whether he had correctly observed the state of the cloud, *i e*, growing, steady or melting Comparison was therefore made in every case with the weather reports from the stations in question, and pilot's remarks, when obviously incorrect, were amended accordingly.

The author wishes to thank all those pilots who endeavoured, successfully or otherwise, to take these special observations, particularly Flight Lieutenant V. Q. Blackden, whose personal co-operation whilst he was at Peshawar, was most valuable. Thanks are also due to Air Commodore A S Barratt, C M G, and Air Commodore B E Sutton, D.S.O., O B E, M C,—successively commanding, No 1 (Indian) Group Headquarters, R. A. F—for kindly giving permission for these observations to be carried out.

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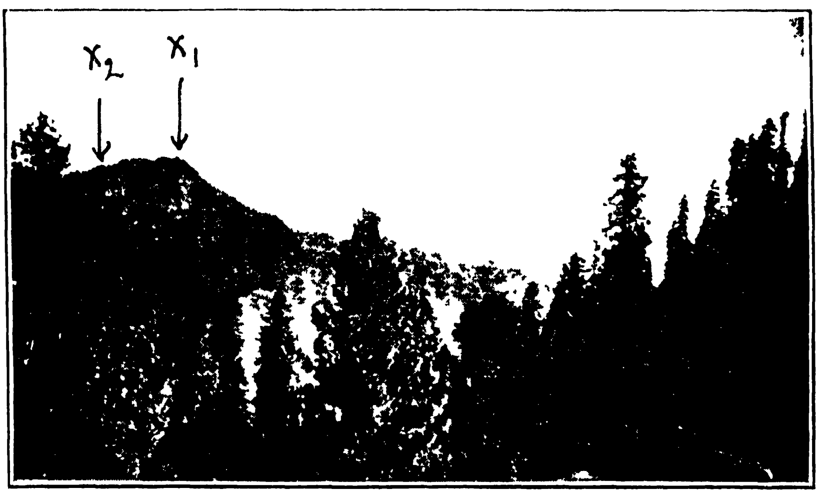
APPENDIX.

Whilst on leave, during the monsoon season, at Thandiani, a hill station approximately 9,000 feet high, in the Hazara District of the N.-W. F. P., the author observed that on fine days a patch of cumulus cloud formed almost regularly on or over the peak of a hill known locally as 'Panther Hill'. As this peak is easily accessible it was considered a good opportunity to take observations (i) in or immediately below the cloud, and (ii) below but to the side of the cloud. The ridge on which the observations were made forms a rough escarpment with a fairly steep slope to the South East– the direction from which the monsoon current normally approaches the station. To the north west the ridge slopes gradually downwards with spurs running outwards on each side in approximately a north east or south west direction. The diagram below illustrates the relative position of the two points of observations, *i.e.*, X_1 at the highest point of the ridge overlooking the valley below, and X_2 a point somewhat lower down and approximately a half a mile distant from X_1. Actually the places chosen for X_1 and X_2 varied a little according to the size of the cloud.



The average time taken to reach X_2 from X_1 after taking the first set of observations was about 10 minutes. An ordinary Assmann psychrometer was used to take dry bulb and wet bulb readings. Small pieces of thin paper served to study the air motion near the peak and a rough estimate was made of the thickness of the cloud. Precautions were taken to avoid direct radiation on the thermometer stems. The results are given in *Table II*. It will be seen that the air immediately below or in the cloud was slightly warmer than the air to the side when the cloud was growing—the difference being 0·5°F on the average. On the occasions when the cloud was melting very little difference was recorded. On 2.9.33 the wet bulb reading inside the cloud was 0·3°F. higher than the dry bulb. On two occasions when readings were taken inside the cloud the percentage humidity was less than 100%, *i.e.*, on 15.8.33 and 22.8.33. No coronae were observed, but on 26.8.33 the phenomenon known as the 'Brocken spectre' was seen inside the cloud. It is hoped to take a more complete set of these observations at Thandiani next year.

TABLE I.

Station ..	Peshawar.	Time of taking off ..	1410 hrs.
Squadron .	20 (A C)	Time of maximum height.	1500 ,,
Date	11-1-32	Time of landing .	1525 ,,

Height above ground. ft. (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	62	52	50	Sky lightly covered with Ci St , A St , and A Cu at first—becoming heavily covered with Ci Cu , Ci St and A Cu , also Cu over hills during morning Mainly overcast with A St , A Cu and Cu in afternoon and evening—clearing gradually at night Pilot reported slight 'bumpiness' from 7,000 feet to base of cloud Readings were taken inside Cu cloud, base at 8 200 feet, thickness 500 feet The cloud appeared to be still growing but may have reached a 'steady' state as it began to dissolve soon after the observations were made The dry bulb was the same outside and inside the cloud at its base, but higher inside at the top The wet bulb was higher inside High lapse-rate from ground to 1,000 feet and superadiabatic lapse-rate below cloud from 7,000 feet to 8,000 feet Lapse rate inside cloud equal to saturated adiabatic Stable layer above top of cloud
10	57	48	54	
20	55	44	43	
30	53·5	41	34	
40	50	40	43	
50	46	34	29	
60	42	32	36	
70	39	32	52	
80	32	30	83	
82	31 (31)	30 (31)	91 (100)	
85	29 (30)	27 (30)	81 (100)	
87	(29 5)	(29 5)	(100)	
88	28	25	73	
90	28	24	64	
100	28	23	54	
110	26	20	42	

Station	Peshawar	Time of taking off	0930 hr
Squadron	20 (A C)	Time of maximum height	1015 ,,
Date .	12-1-32	Time of landing .	1045 ,,

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	54	49	70	Sky heavily covered with A Cu and Cu in morning occasional bright intervals—cloud decreasing overhead at midday—becoming clear in afternoon/evening except for Cu and Cu Nb over hills—clear at night Readings were taken inside growing Cu cloud, base at 7,500 feet, thickness 1,500 feet Observations were not made outside top of cloud at 9,000 feet Except at the base of the cloud where it was the same, the dry bulb was higher inside the cloud than outside The wet bulb was also higher inside Superadiabatic lapse rate from 4,000 feet to 5,000 feet and also inside cloud High lapse-rate above cloud from 10,000 feet to 11,000 feet Humidity less than 100 per cent at base of cloud. Wet bulb 0 5° higher than dry bulb at 8,500 feet inside cloud
10	53	45	56	
20	53	42	41	
30	50	40	43	
40	47	38	44	
50	41	35	60	
60	38	34	72	
70	34	30	68	
75	30 5 (30 5)	29 5 (30)	91 (95)	
80	27 5 (29)	26 5 (29)	90 (100)	
85	25 5 (26 5)	24 (27)	83 (100)	
90	(23)	(23)	(100)	
100	20	19	83	
110	15	14	79	
120	11	8	52	
130	9	7	61	
140	5	3	57	

TABLE I—*contd.*

Station	Kohat	Time of taking off	0830 hrs.
Squadron	27 (B)	Time of maximum height	0925 ,,
Date	31-1-32	Time of landing	1000 ,,

Height above ground ft (hundreds)	Dry Bulb F		Wet Bulb F		Humidity per cent		Weather conditions and remarks.
0	56		51		72		Mainly overcast all day with A. Cu. and Cu. cloud Readings were taken inside Cu and A. Cu. cloud base at 7,900 feet and 14,000 feet respectively The thickness of the Cu cloud was 1,200 feet The cumulus cloud appeared to be growing but was spreading out laterally at the top The dry bulb was the same inside and outside the lower half of the cloud but lower inside the upper half Wet bulb higher inside. High lapse rate from 6,000 feet to 7,000 feet below cloud Superadiabatic lapse-rate inside cloud Inversion at top of cloud Wet bulb 0.5° higher than dry bulb at 8,800 feet inside cloud.
10	56		50		68		
20	55		49		68		
30	52		47		72		
40	48		44		75		
50	44		40		74		
60	40		37		80		
70	35		34		92		
79	33.5	(33.5)	32	(33.5)	88	(100)	
80	33		31		84		
85	32	(32)	30.5	(32)	88	(100)	
88	30.5	(29.5)	29	(30)	87	(100)	
90	30	..	28		92		
91		(30.5)		(30.5)		(100)	
95	31		29		84		
100	32		29		77		
110	29		25		65		
120	26		23		71		
130	21		19		74		
140	17	(17)	17	(17)	100	(100)	

Station	Risalpur.	Time of taking off	1035 hrs.
Squadron	39 (B)	Time of maximum height	1130 ,,
Date	1-2-32	Time of landing	1200 ,,

Height above ground ft (hundreds)	Dry Bulb F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	54		52		88		Sky heavily covered with Cu., Cu Nb., A Cu and A St all day (base of A Cu and A St above 15,000 feet) Pilot reported slight 'bumpiness' inside cloud Readings were taken inside growing Cu Nb cloud, with 'anvil', base at 7,400 feet, thickness 3,600 feet Observations were not made at 9,000 feet inside cloud Dry bulb was higher inside than outside the lower half of the cloud, slightly lower inside at the centre, but the same inside and outside the upper part of the cloud Wet bulb was higher inside Lapse-rate greater than saturated adiabatic in lower half but less than saturated adiabatic in upper half of cloud Stable layer above top of cloud Humidity less than 100 per cent at 8,000 feet in cloud.
10	51		48		82		
20	49		46		81		
30	46		43		81		
40	42		39		80		
50	39		36.5		85		
60	36		34		85		
70	34		33		92		
74	31	(31.5)	30	(31.5)	91	(100)	
80	29	(30)	27	(29)	80	(91)	
85	27	(28)	26	(28)	90	(100)	
90	26		25.5		94		
95	25	(24)	24	(24)	88	(100)	
100	23	(23)	22	(23)	85	(100)	
105	22	(22)	21	(22)	85	(100)	
110	21	(21)	20	(21)	84	(100)	
115	21		19		74		
120	20		17		64		
130	17		14		60		
140	14		11		56		
150	9		8		74		

TABLE I—*contd.*

Station	Risalpur	Time of taking off	0935 hrs
Squadron	11 (B)	Time of maximum height	0955 ,,
Date	13-2-32	Time of landing	1015 ,,

Height above ground ft. (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	47	46	94	Overcast with Nb and A St all day—frequent showers. Pilot reported 'bumpiness' from 1,500 feet to base of cloud. Readings were taken inside Nb clouds base at 1,900 feet thickness 4,300 feet. It was not possible to make observations outside the cloud. Lapse rate in cloud mainly equal to the saturated adiabatic. Humidity less than 100 per cent at 5,000 feet in cloud
10	46	45	94	
20	(42)	(42)	(100)	
30	(39)	(39)	(100)	
40	(36)	(36)	(100)	
50	(34)	(33)	(93)	
60	(30)	(30)	(100)	
70	27	26	9[illegible]	

Station	Peshawar	Time of taking off	1000 hrs
Squadron	20 (A C)	Time of maximum height	1055 ,,
Date	18-2-32	Time of landing	1130 ,,

Height above ground ft (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks
0	54		49		64		Sky heavily covered with Ci St, Ci Cu, A. St, A Cu, and St Cu, at first—clearing rapidly overhead in forenoon but Cu and Cu Nb increasing over hills—lightly clouded with Ci, Ci St, and also detached Cu and Cu Nb over hills in afternoon and evening—clear at night. Pilot reported 'bumpiness' between 4,000 feet and 5,000 ft and in top of cloud. Readings were taken inside growing Cu cloud, base at 8,200 feet, thickness 1,500 feet. The dry bulb was the same or slightly higher inside than outside the cloud. Wet bulb was higher inside. High lapse rate from 7,000 feet to 8,000 feet below cloud, and from 11,000 feet to 12,000 feet above cloud. Lapse-rate inside cloud mainly greater than saturated adiabatic. Wet bulb 0.5 higher than dry bulb at 8,500 feet in cloud. Humidity very low from 2,000 feet to 4,000 feet and from 14,000 feet to 15,000 feet
10	55		42		37		
20	54		40		26		
30	50		37		26		
40	47		35		26		
50	42		32		36		
60	38		30		44		
70	35		32		77		
80	30		29		90		
82	29	(29)	28	(29)	90	(100)	
85	27	(27.5)	25	(28)	89	(100)	
90	25	(25)	24	(25)	88	(100)	
95	23	(24)	22	(24)	85	(100)	
97		(21)		(21)		(100)	
100	20		19		83		
110	17		16		82		
120	12		11		76		
130	9		7		61		
140	6		2		31		
150	2		—2		19		

TABLE I—*contd.*

Station . .	Peshawar	Time of taking off . .	1020 hrs.
Squadron	20 (A C)	Time of maximum height .	1110 „
Date . . .	23 3 32	Time of landing	1140 „

Height above ground. ft (hundreds).	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks.
0	67	60	67	Overcast with A Cu, A St, St Cu, Cu Nb. and Nb in morning occasional showers and squally winds—brightening a little at midday, but again overcast in afternoon with A St, St Cu, Cu Nb and Nb – further showers—cloud decreasing in evening—variable sky at night. Pilot reported great 'bumpiness' at all heights. Readings were taken inside St Cu cloud, base 11,000 feet, thickness more than 4,000 feet. It was not considered advisable to enter the towering masses of Cu and Cu Nb near the hills. Moreover, readings could not conveniently be taken outside the St Cu. cloud. Lapse-rate in cloud mainly greater than saturated adiabatic.
10	67	60	69	
20	70	63	70	
30	65	58	72	
40	59	53	70	
50	55	52	84	
60	52	49	83	
70	47	43	77	
80	44	41	81	
90	38	36	88	
100	36	35	96	
110	(32)	(31)	(93)	
120	(30)	(30)	(100)	
130	(26)	(26)	(100)	
140	(20)	(20)	(81)	
150	(17)	(17)	(100)	

Station .	Peshawar	Time of taking off .	1110 hrs.
Squadron	20 (A C)	Time of maximum height	1200 „
Date	24-3-32	Time of landing	1225 „

Height above ground ft (hundreds)	Dry Bulb F	Wet Bulb F	Humidity per cent	Weather conditions and remarks
0	77	68	63	Sky moderately covered with Ci overhead and a little detached Cu over hills at first - becoming heavily covered towards midday with Ci Cu, A Cu, and Cu—overcast in afternoon with Ci Cu, A Cu, Cu Nb., and Cu – clearing gradually in evening—lightning in distance at night. Pilot reported 'bumpiness' from ground to 3,000 feet, and from 9,000 feet to top of A Cu cloud. Readings were taken inside growing Cu. cloud base at 4,900 feet, thickness 800 feet, and in growing A Cu, 'castellatus' cloud, base at 11,400 feet, thickness 2,500 feet. Both dry bulb and wet bulb were higher inside the cumulus cloud. The dry bulb was lower inside than outside the bottom part of the alto-cumulus cloud but slightly higher inside at the top. The wet bulb was mainly higher inside than outside the alto-cumulus cloud. The lapse-rate was superadiabatic from the ground to 1,000 feet and from 2,000 feet to 3,000 feet—below the cumulus cloud, and also from 9,000 feet to 11,000 feet—below the alto-cumulus cloud. The lapse-rate in the cumulus cloud was less than the saturated adiabatic but greater in the alto-cumulus cloud. An inversion was recorded at the top of the alto-cumulus cloud. The wet bulb was 1° higher than the dry bulb at 13,800 feet in the alto-cumulus cloud.
10	70.5	59	53	
20	67	53.5	42	
30	61	52.5	59	
40	58	52.5	72	
49	53.5 (54.5)	52.5 (54.5)	95 (100)	
55	52.5 (53)	52 (53)	97 (100)	
57	(52.5)	(52.5)	(100)	
60	52	51	94	
70	48	46	87	
80	43.5	42	90	
90	39	37	88	
100	34	32	87	
110	28.5	27.5	91	
114	26.5 (26)	25.5 (26)	88 (100)	
120	25 (24)	24 (24)	86 (100)	
130	20 (20)	18.5 (20)	77 (100)	
138	15.5 (16)	13 (17)	63 (100)	
139	(17)	(17)	(100)	
145	14.5	11	53	
150	12	10	64	

TABLE 1—*contd.*

Station ..	.. Peshawar	Time of taking off	1050 hrs.
Squadron	.. 20 (A C)	Time of maximum height.	1130 ,,
Date ..	.. 27-3-32	Time of landing	. 1155 ,,

Height above ground. ft (hundreds)	Dry Bulb °F.		Wet Bulb °F		Humidity per cent		Weather conditions and remarks
0	74		62		51		Sky heavily covered with Ci and Ci St at first, also detached Cu over hills—clearing a little overhead in forenoon, but Cu and Cu Nb developing over hills—overcast in afternoon with Ci, Ci St, Cu Nb, and Cu—also St Cu forming in evening—cloudy at night Pilot reported 'bumpiness' just below cloud Readings were taken inside growing Cu Nb cloud, base 7,850 feet thickness 2,250 feet The dry bulb was either the same inside and outside the cloud or slightly lower inside The wet bulb was higher inside There was a high lapse-rate from 1,000 feet to 5,000 feet below the cloud and a superadiabatic lapse-rate inside Stable layer above top of cloud Wet bulb was 0 5 higher than the dry bulb at 9,500 feet in the cloud
10	70		59		54		
20	65		54		51		
30	60		50		52		
40	55		48		63		
50	50		44		66		
60	46		42		75		
70	43		41		87		
78·5	40	(39 5)	39	(39 5)	93	(100)	
80	39	(39)	38	(39)	93	(100)	
85	37	(36)	36	(36)	96	(100)	
90	35	(35)	34	(35)	96	(100)	
95	33	(32 5)	32	(33)	94	(100)	
100	30	(30)	29	(30)	92	(100)	
101	31	(30)	29	(30)	83	(100)	
105	29		28		91		
110	29		26		74		
120	25		24		86		
130	21		20		81		
140	19 5		18		78		
150	16		15		79		

Station ..	.. Kohat.	Time of taking off	0935 hrs
Squadron	.. 60 (B).	Time of maximum height	1010 ,,
Date ..	. 29-3-32	Time of landing	1040 ,,

Height above ground. ft. (hundreds.)	Dry Bulb °F.		Wet Bulb °F.		Humidity per cent		Weather conditions and remarks
0	69		63		72		Sky heavily covered with Ci St, A St, Cu. Nb, and Cu cloud all day Pilot reported 'bumpiness' from ground to 2,000 feet and also inside cloud Readings were taken inside growing Cu. cloud the top of which was flat, base at 6,000 ft thickness 1,600 ft Base of A St cloud was not reached The dry bulb was higher inside than outside the lower half of the cloud but lower inside the upper half The wet bulb was higher inside The lapse-rate was superadiabatic from the ground to 2,000 feet and also inside the cloud—especially at the top.
10	62		58		81		
20	57		55		91		
30	54		52		90		
40	50		49		94		
50	48		47		93		
60	45	(46)	43	(46)	87	(100)	
65	44	(45)	42	(45)	87	(100)	
70	42	(43)	39	(43)	80	(100)	
75	41	(40)	38	(40)	80	(100)	
76	40	(39)	38	(39)	86	(100)	
78	39		37		87		
80	38		36		86		
90	34		32		86		
100	32		30		84		
110	29		28		91		
120	27		26		88		
130	25		23		78		
140	22		20		74		
150	18		17		81		

TABLE I—*contd.*

Station ..	Peshawar	Time of taking off	0935 hrs.
Squadron .	20 (A C)	Time of maximum height.	1050 ,,
Date .	1-5-32	Time of landing	1120 ,,

Height above ground. ft (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent.		Weather conditions and remarks
0	76		64		52		Sky heavily covered with Ci St, A St also detached Cu over hills at first—clearing considerably overhead in forenoon, but Cu and Cu Nb developing over hills—sky heavily covered in afternoon with A Cu, A St, Cu Nb and Cu—cloud decreasing in evening sky clear at night Pilot reported 'bumpiness' at all heights, especially between 2,000 feet and 4,000 feet Readings were taken inside growing Cu and Cu Nb cloud—base of first layer (Cu) at 8,100 feet, thickness 150 feet, base of second layer (Cu) at 9,000 feet, thickness 300 feet, base of third layer (Cu Nb) at 9,800 feet, thickness 2,400 feet Dry bulb was mainly the same inside and outside cumulus cloud, but slightly higher inside cumulo-nimbus cloud except at top where it was a little higher outside The wet bulb was higher inside cloud Super-adiabatic lapse-rate from ground to 1,000 feet and from 2,000 feet to 4,000 feet—below cloud Lapse-rate in cloud mainly equal to saturated adiabatic High lapse-rate from 13,000 feet to 15,000 feet—above cloud Wet bulb 1° higher than dry bulb at 9,000 feet in cloud
10	70		61		62		
20	68		58		57		
30	62		54		63		
40	56		49		63		
50	54		46		58		
60	49		44		71		
70	45		42		81		
81	40	(40)	39	(40)	93	(100)	
82·5	39	(39·5)	38	(39·5)	93	(100)	
85	39·5		38		92		
90	37	(37)	36	(38)	96	(100)	
93	36	(36)	35	(36)	95	(100)	
95	36		35		95		
98	35	(36)	34	(36)	95	(100)	
100	35	(35)	34	(35)	95	(100)	
105	33	(33·5)	32	(33·5)	94	(100)	
110	31	(32)	30	(32)	92	(100)	
115	30	(31)	29	(31)	91	(100)	
120	29	(29)	28	(29)	90	(100)	
122	28	(27)	27	(27)	89	(100)	
125	27		26		88		
130	25		23		78		
140	20		18		72		
150	15		14		79		
160	12		11		76		

Station	Risalpur	Time of taking off	0945 hrs.
Squadron	39 (B)	Time of maximum height	1025 ,,
Date .	21-6-32	Time of landing	1045 ,,

Height above ground. ft (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	84		74		62		Sky mainly overcast all day with Cu, Cu Nb., A Cu. and A St cloud Pilot reported 'bumpiness' from 1,000 feet to 2,000 feet and just below cloud Readings were taken inside growing Cu cloud, base at 7,050 feet, thickness 1,250 feet, and in A Cu cloud, base at 12,800 feet, thickness 700 feet No observations were made outside A Cu cloud Dry-bulb higher inside cloud than outside except at the top, where it was the same. Wet bulb higher inside High lapse-rate from 1,000 feet to 2,000 feet and super-adiabatic lapse-rate from 6,000 feet to base of cloud Lapse-rate inside cloud mainly greater than saturated adiabatic.
10	80		69		61		
20	75		66		64		
30	73		64		64		
40	69		64		78		
50	65		62		86		
60	62		60		91		
70·5	56	(57)	55	(57)	94	(100)	
75	55	(56)	54	(56)	94	(100)	
80	53	(54)	52	(54)	94	(100)	
83	53	(53)	52	(53)	94	(100)	
85	52		50		91		
90	50		49		96		
100	47		45		91		
110	42		40		89		
120	36		35		91		
130	..	(33)	..	(33)	..	(100)	
140	32		31		91		
150	30		29		91		

TABLE I—*contd.*

Station	Peshawar	Time of taking off	0910 hrs.
Squadron .	20 (A C)	Time of maximum height	0950 ,,
Date ..	10-7-32	Time of landing ..	1015 ,,

Height above ground ft (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	84		75		66		Sky mainly overcast with St Cu. at first, A St visible through breaks—Cu and Cu Nb forming over hills during morning—clearing a little overhead towards midday, but becoming overcast in afternoon with Ci St , A St , Cu Nb, and Cu—cloud decreasing in evening—clear at night Pilot reported ' bumpiness ' between 4,000 feet and 5,000 feet Readings were taken inside growing Cu Nb. cloud, base at 3,950 feet, thickness 5,650 feet A St cloud was not entered Dry bulb was the same inside and outside at the base of the cloud, and lower inside at top, otherwise higher inside Wet bulb was higher inside except at top where it was the same as outside Superadiabatic lapse-rate from 2,000 feet to 3,000 feet below cloud Variable lapse-rate inside cloud exceeding saturated adiabatic from 6,000 feet to 7,000 feet and from 8,000 feet to top Low lapse-rate from 12,000 feet to 15,000 feet—above cloud Inversion at cloud base—change of wind direction from N E to S S W
10	80·5		73·5		74		
20	77		71·5		79		
30	71·5		68		86		
37	67		65		92		
39·5	68	(68)	66	(68)	92	(100)	
45	66	(66·5)	65	(66·5)	96	(100)	
50	64	(64·5)	63	(64·5)	95	(100)	
60	61	(62·5)	59	(62·5)	91	(100)	
70	58	(59)	56	(59)	89	(100)	
80	55	(57)	54	(57)	94	(100)	
90	53·5	(53·5)	52	(53·5)	94	(100)	
96	52·5	(51)	51	(51)	94	(100)	
100	52		51		97		
110	48		46		91		
120	44·5		43·5		94		
130	43·5		43		98		
140	42		41		92		
150	40		39		91		

Station	Peshawar	Time of taking off	0645 hrs.
Squadron .	20 (A C)	Time of maximum height	0725 ,,
Date .	9 8 32	Time of landing	0800 ,,

Height above ground. ft. (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	80		77·5		89		Sky heavily covered with Ci St , Ci Cu , A St , A Cu and Cu at dawn—clearing considerably overhead in forenoon—but becoming overcast at midday with A Cu , A St and masses of Cu and Cu Nb over hills—thunderstorm in afternoon—continuing overcast in evening with A Cu , A St , St Cu , and Cu —variable sky at night Pilot reported ' bumpiness ' in cloud Readings were taken inside growing Cu Nb. cloud, base at 5,800 feet, thickness 4,200 feet Both dry bulb and wet bulb were higher inside the cloud than outside Lapse-rate in cloud greater than saturated adiabatic from base to 8,000 feet Inversion above top of cloud Humidity less than 100 % at 6,000 feet, 9,000 feet and 10,000 feet. Wet bulb 0 5° higher than dry bulb at 8,000 feet in cloud.
10	79		75		85		
20	78		72		77		
30	74		69		80		
40	70		66·5		85		
50	66		63·5		88		
58	62	(63)	60	(63)	91	(100)	
60	60	(62)	57·5	(61·5)	87	(98)	
70	56	(58)	53·5	(58)	86	(100)	
80	53·5	(54)	51	(54·5)	86	(100)	
90	51·5	(51·5)	46·5	(51)	76	(98)	
100	48	(49)	43	(48·5)	74	(98)	
105	47·5		43·5		79		
110	48		44·5		83		
120	45		38·5		62		
130	42		32		42		
140	39		30		43		

TABLE I—*contd.*

Station ..	.. Peshawar	Time of taking off ..	1000 hrs.
Squadron	.. 20 (A C)	Time of maximum height ..	1040 ,,
Date ..	.. 28-12-32.	Time of landing ..	1115 ,,

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F.	Humidity per cent	Weather conditions and remarks
0	52	47 5	72	Sky lightly covered with detached Cu (over hills) in early morning—becoming heavily covered with A Cu and Cu towards midday—mainly overcast in afternoon with Ci St, A Cu, Cu Nb and Cu—light showers in evening—then clearing a little but heavily clouded again at night with further showers and squally winds. Pilot reported 'bumpiness' from 6,000 feet to base of cloud. Readings were taken inside growing Cu cloud, base at 8,000 feet, thickness 600 feet. The dry bulb was the same inside at the base of the cloud but slightly lower inside at the top. The wet bulb was higher inside. Adiabatic lapse-rate from 6,000 feet to base of cloud. Lapse-rate greater than saturated adiabatic inside cloud.
10	48	41	56	
20	47	38	43	
30	43	36	51	
40	39	32	51	
50	36 5	30	52	
60	32	26 5	53	
70	26 5	24	72	
80	21 (21)	19 (21)	74 (100)	
85	19 5 (19)	18 (19)	78 (100)	
90	18 5	16	66	
100	15	11 5	49	
110	12	8 5	45	
120	8 5	5	38	
130	7	3	28	
140	3	—0 5	26	
150	—0·5	—2	53	

Station ..	. Kohat	Time of taking off ..	0905 hrs.
Squadron	. 27 (B)	Time of maximum height ..	0945 ,,
Date ..	.. 15-2-33.	Time of landing .	1025 ,,

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	50	44	62	Sky heavily covered with A Cu and Cu. at first—cloud decreasing temporarily in forenoon but sky still partially covered with A Cu and Ci Cu at midday—cloud decreasing rapidly in afternoon—lightly clouded in evening with Ci Cu—clear at night. Pilot reported slight 'bumpiness' from 4,000 feet to cloud base. Readings were taken inside melting Cu cloud (No observations made outside cloud at 10,000 feet) Base of first layer at 5,900 feet, thickness 1,700 feet, base of second layer at 9,000 feet, thickness 1,000 feet. The dry bulb was higher inside than outside the first layer of cloud but lower inside the second layer. The wet bulb was higher inside the cloud—particularly in the first layer. High lapse-rate from 4,000 feet to 5,000 feet below cloud, superadiabatic lapse-rate inside cloud. Stable layer above top of cloud.
10	49	43	63	
20	46	40	62	
30	43	36	52	
40	40	33 5	51	
50	35	30	61	
59	31 (32)	27 (32)	64 (100)	
60	(32)	(32)	(100)	
65	29 (31)	26 (31)	72 (100)	
70	28 (30)	25 (30)	71 (100)	
76	26 (28)	24 (28)	78 (100)	
80	25	24	88	
90	21 (20)	19 (20)	85 (100)	
100	(18)	(18)	(100)	
110	16	14	71	
120	14	11	56	
130	12	8 5	48	
140	10	7	51	
150	8	5	49	

TABLE I—*contd.*

Station	Risalpur	Time of taking off	0705 hrs.
Squadron	39 (B)	Time of maximum height..	0740 ,,
Date ..	13-5-33	Time of landing	0815 ,,

Height above ground ft (hundreds)	Dry Bulb F	Wet Bulb F	Humidity per cent	Weather conditions and remarks
0	73	65	66	Sky heavily covered with A Cu and St Cu in early morning moderately covered with A Cu and Cu in forenoon partially covered in afternoon and evening with A Cu variable sky (passing A Cu) at night
10	69	62	69	
20	66	60	73	
30	63	57.5	74	
40	60	55	76	
50	57	52	76	
60	54	49	73	Pilot reported slight 'bumpiness' from 11,000 feet to 13,000 feet
70	50	46	77	
80	[illegible]	43	81	Readings were taken inside melting St Cu cloud base at 8,500 feet, thickness 200 feet A Cu (at 13,000 feet) not entered
86	45 (43)	42 (42)	83 (96)	
90	43	39	76	
100	40	36	75	The dry bulb was lower inside the cloud than outside, but the wet bulb was the same
110	36	33	79	
120	31	27	65	
130	26.5	23	70	
140	23	20	66	
150	20	18	73	

Station ..	.. Peshawar	Time of taking off	1035 hrs.
Squadron	.. 20 (A C)	Time of maximum height .	1110 ,,
Date ..	23-6-33	Time of landing	1140 ,,

Height above ground ft (hundreds)	Dry Bulb F	Wet Bulb F	Humidity per cent	Weather conditions and remarks
0	82	76	77	Overcast in early morning with A St, A Cu, St Cu and Cu—occasional showers—brightening in forenoon with considerable decrease of cloud—sky partially covered with A Cu and Ci Cu in evening—clear sky at night
10	75	70.5	82	
20	71	67	82	
30	68	64	82	
40	65	61	81	
50	62	59	86	
55	61 (60)	57 (60)	76 (100)	Readings were taken inside melting Cu. cloud, base at 5,200 feet, thickness 400 feet
60	60	55	76	
70	57	51	70	The dry bulb was lower and the wet bulb higher inside the cloud than outside Super-adiabatic lapse-rate from ground to 1,000 feet
80	54	49	73	
90	51	47	78	
100	48	44	78	
110	46	43	82	
120	44	36	54	
130	41	32	46	
140	36.5	30	56	
150	32	28	56	

TABLE I—*contd.*

Station	.. Peshawar.	Time of taking off	.. 0930 hrs.
Squadron	. 20 (A C)	Time of maximum height	.. 1015 „
Date	. 25-6-33	Time of landing	. .. 1050 „

Height above ground. ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks.
0	93	79	54	Sky lightly covered with A Cu and Cu. at first—becoming partially covered with A. Cu, Cu Nb and Cu in forenoon—heavily covered in afternoon and overcast in evening with Cu Nb and Cu —clearing overhead at night, lightning over hills. Pilot reported 'bumpiness' from ground to 1,000 feet Readings were taken inside growing Cu cloud, base at 7,500 feet, thickness 1,100 feet. Cu Nb (base at 6,200 feet) over hills not entered A Cu above 15,000 feet The dry bulb was higher inside the cloud at its base but lower inside at the top The wet bulb was higher inside the cloud at its base but the same as outside at the top High lapse-rate from ground to 5,000 feet and superadiabatic lapse-rate inside cloud. The humidity in the cloud at 8,000 feet was less than 100%
10	88	75	57	
20	83	71	58	
30	78	69	67	
40	73	67	75	
50	68	64	82	
60	64	61	86	
70	60	58	90	
75	59 (60)	56 (60)	85 (100)	
80	58 (57)	56 (56)	88 (95)	
85	(56)	(56)	(100)	
87	57 5	52	76	
90	55	48	67	
100	51	39	41	
110	47	38	51	
120	44	36	55	
130	41	35	63	
140	39	34	66	
150	36	33	77	

Station	Risalpur	Time of taking off	0705 hrs
Squadron	. 11 (B)	Time of maximum height	. 0745 „
Date	.. 10-7-33.	Time of landing	. .. 0815 „

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks.
0	81	76	79	Sky moderately covered with Cu at dawn—becoming partially covered in forenoon and heavily covered after midday with Cu Nb —duststorm in afternoon—sky clearing in evening Readings were taken in growing Cu Nb. cloud, base at 4,000 feet, thickness 3,700 feet Observations were not taken at 4,000 feet and 4,500 feet outside cloud and were missed at 6,500 feet inside The dry bulb was the same inside and outside the bottom part of the cloud but lower inside than outside the top part The wet bulb was mainly higher inside than outside the cloud. The lapse-rate in the cloud was greater than the saturated adiabatic except near the base At 5,000 feet, 6,000 feet and 7,000 feet in the cloud the wet bulb was 1 0° higher than the dry bulb
10	82	75	74	
20	78	73	81	
30	73	70	88	
40	(69)	(69)	(100)	
45	(68)	(68)	(100)	
50	66 (66)	65 (67)	96 (100)	
55	64 (64)	63 (64)	96 (100)	
60	63 (62)	62 (63)	96 (100)	
65	62	60	91	
70	59 (58)	58 (59)	95 (100)	
75	57 (55)	55 (55)	89 (100)	
80	56	54	89	
90	53	51	92	
100	50	47	86	
110	47	44	86	
120	45	41	76	
130	43	39	74	
140	42	39	80	
150	40	37	79	

TABLE I—*contd.*

Station ..	Risalpur.	Time of taking off ..	0635 hrs.
Squadron	11 (B)	Time of maximum height..	0720 „
Date ..	.. 12-7-33.	Time of landing ..	0755 „

Height above ground ft. (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	84		80		84		Sky heavily covered with A Cu and Cu in early morning—becoming moderately covered in forenoon—clearing completely in afternoon
10	83		77		78		Pilot reported slight 'bumpiness' from 4,000 feet to base of cloud
20	81		75		78		Readings were taken in Cu. cloud, which appeared to be melting or in a 'steady' state, base at 5,500 feet, thickness 4,100 feet Observations were not made inside peak of cloud.
30	78		73		81		The dry bulb was appreciably lower inside the cloud than outside The wet bulb was mainly higher inside up to 6,500 feet but lower inside from 7,000 feet to 8,500 feet. The lapse-rate in the cloud was greater than the saturated adiabatic Stable layer existed above top of cloud
40	74		69		79		
50	70		66		83		
55	68	(65)	64	(65)	83	(100)	
60	66	(63)	63	(63)	86	(100)	
65	64	(61)	61	(62)	86	(100)	
70	62	(59)	60	(59)	91	(100)	
75	60	(57)	58	(57)	90	(100)	
80	58	(55)	56	(55)	89	(100)	
85	56	(53)	54	(53)	92	(100)	
90	54	(52)	52	(52)	92	(100)	
96	52		50		92		
100	50		49		96		
110	48		46		91		
120	46		43		83		
130	43		39		74		
140	41		36		67		
150	40		34		62		

Station ..	Risalpur	Time of taking off .	0715 hrs.
Squadron	11 (B)	Time of maximum height..	0755 „
Date ..	. 16-7-33	Time of landing ..	0825 „

Height above ground ft. (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	79		75		83		Sky overcast with A St, A Cu, and St Cu. cloud in early morning—clearing considerably in forenoon—heavily covered with Ci Cu at midday—moderately covered with Ci Cu in evening
10	76		74		91		Pilot reported slight 'bumpiness' below cloud
20	74		71		87		Readings were taken inside melting St Cu cloud, base at 5,100 feet, thickness 1,100 feet and in A St cloud at 15,000 feet.
30	72		68		83		The dry bulb was lower inside than outside at the base of cloud but the same at the top. The wet bulb was the same inside and outside The lapse-rate in the cloud was less than the saturated adiabatic. The humidity in the cloud was less than 100%.
40	68		65		87		
50	65		63		91		
55	64	(63)	62	(62)	91	(96)	
60	62	(62)	60	(60)	91	(91)	
65	61		58		90		
70	59		56		86		
80	55		52		84		
90	53		50		84		
100	51		47		78		
110	48		44		78		
120	44		41		81		
130	41		39		87		
140	37		36		93		
150	..	(33)	..	(33)	100		

TABLE I—*contd.*

Station ..	.. Risalpur	Time of taking off	. 1015 hrs.
Squadron	.. 39 (B).	Time of maximum height	. 1045 „
Date ..	.. 19-7-33	Time of landing	.. 1110 „

Height above ground. ft (hundreds)	Dry Bulb °F	Wet Bulb °F.	Humidity per cent	Weather conditions and remarks.
0	86	79	75	Sky heavily covered with A Cu and Cu. at first—cloud decreasing in forenoon—partially covered with A Cu and Cu at midday —clearing completely in afternoon. Pilot reported slight 'bumpiness' from ground to 2,000 feet. Readings were taken in Cu cloud, which appeared to be melting or in a "steady" state, base at 6,200 feet, thickness 1,100 feet. The dry bulb was lower inside the cloud than outside, but the wet bulb was higher inside. Superadiabatic lapse-rate from ground to 2,000 feet. Lapse rate in cloud greater than saturated adiabatic. The wet bulb at 7,000 feet in the cloud was 1·0° higher than the dry bulb.
10	79·5	75	82	
20	74	71	87	
30	72	69	87	
40	70	67	87	
50	67	65	91	
60	65	63	91	
62	64 (63)	62 (63)	91 (100)	
70	62 (61)	60 (62)	90 (100)	
73	60 (59)	58 (59)	92 (100)	
75	60	58	92	
80	58	56	91	
90	55	53	90	
100	51·5	49	88	
110	48	45	84	
120	45	43	88	
130	41	39	87	
140	38	33	68	
150	36	28	47	

Station .	Risalpur	Time of taking off	0635 hrs
Squadron	39 (B)	Time of maximum height .	0705 „
Date	21-7-33	Time of landing	.. 0730 „

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F.	Humidity per cent.	Weather conditions and remarks.
0	78	74	83	Sky partially covered with Cu (mostly over hills) at dawn—cloud decreasing in forenoon—clear after midday. Readings were taken inside melting Cu cloud, base at 7,000 feet, thickness 200 feet. The dry bulb was lower inside than outside the cloud, but the wet bulb was higher inside. Humidity in cloud less than 100%.
10	76	73	87	
20	74	72	91	
30	72	69	87	
40	69	65	82	
50	66	62	81	
60	63	59	81	
70	60	56	80	
71	60 (59)	56 (57)	80 (89)	
80	57	52	76	
90	54	49	76	
100	51	45	69	
110	48	42	68	
120	45	39	65	
130	42	37	70	
140	38·5	34·5	74	
150	35	32	79	

TABLE I—*contd.*

Station ..	.. Peshawar	Time of taking off	.. 0915 hrs.
Squadron	.. 20 (A C).	Time of maximum height	.. 0955 „
Date .	. 27-7-33	Time of landing .	1025 „

Height above ground ft. (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks.
0	85	78	74	Overcast at first with St Cu and Cu—clearing considerably in forenoon—heavily clouded again in afternoon and evening with A St A Cu, and Cu—mainly overcast at night
10	80	75	82	
20	75 5	72	79	
30	71	69	92	
40	68	65	87	
45	68 (66)	66 (66)	92 (100)	Pilot reported slight 'bumpiness' in cloud
50	65 (65)	64 (65)	96 (100)	Readings were taken inside Cu cloud, which appeared to be melting or in a "steady" state, base at 4,500 feet, thickness 1,100 feet
55	64 (64)	62 (64)	92 (100)	
60	63	60	86	
70	61	55	72	
80	58	49	56	The dry bulb was the same inside and outside the cloud except at the base where it was lower inside The wet bulb was the same inside and outside the base of the cloud but higher inside at the top There was a high lapse-rate from the ground to 1,000 feet The lapse-rate in the cloud was less than the saturated adiabatic
90	55	43	44	
100	52	44	61	
110	49	44	75	
120	45	39	66	
130	42	34	53	
140	39	29	39	
150	36	28	47	

Station ..	Kohat	Time of taking off	0925 hrs
Squadron	60 (B)	Time of maximum height	1005 „
Date ..	2-8-33	Time of landing	1040 „

Height above ground ft. (hundreds)	Dry Bulb °F.	Wet Bulb °F.	Humidity per cent	Weather conditions and remarks
0	85	77	71	Sky moderately covered with A Cu and Cu at first—becoming partially covered towards midday and heavily covered in afternoon and evening with A. Cu, A St, Cu Nb, and Cu
10	79	74	80	
20	74	71	87	
30	69	68	96	
32	68 (69)	67 (69)	97 (100)	
40	66 (67)	65 (67)	95 (100)	Pilot reported 'bumpiness' from ground to base of cloud
50	63 (64)	61 (64)	90 (100)	
60	61	57	80	Readings were taken inside growing cumulus cloud, base at 3,200 feet, thickness 1,850 feet
70	58	53	76	
80	56	48	59	
90	53	46	65	Both dry bulb and wet bulb were higher inside the cloud than outside Superadiabatic lapse-rate from ground to 1,000 feet. Lapse-rate in cloud approximately equal to the saturated adiabatic
100	49	44	73	
110	45	41	76	
120	41	37	75	
130	39	34	68	
140	37	31	59	
150	35	29	58	

TABLE I—*contd.*

Station ..	Kohat	Time of taking off	. 0920 hrs.
Squadron	60 (B)	Time of maximum height ..	1005 „
Date .	4-8-33.	Time of landing	1045 „

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks.
0	84	71	54	Sky moderately covered with A. Cu. and Cu. in early morning—becoming heavily covered with A Cu and Cu towards midday—cloud decreasing in afternoon—lightly clouded in evening with A Cu —clear at night Readings were taken inside growing Cu. cloud, base at 6,700 feet, thickness 800 feet Both dry bulb and wet bulb were higher inside the cloud than outside High lapse-rate from ground to 1,000 ft Lapse-rate in cloud greater than the saturated adiabatic Humidity at base of cloud was less than 100 %
10	79	68	58	
20	75	66	64	
30	72	64	68	
40	69	62	71	
50	66	61	77	
60	62	58	80	
67	60 (61)	57 (60)	85 (95)	
70	58 (59)	55·5 (59)	87 (100)	
75	56 (57)	53 (57)	84 (100)	
80	55	51	79	
90	52	46	70	
100	48	42	68	
110	45	39	65	
120	41	35	63	
130	38	32	62	
140	34	30	71	
150	30	28	83	

Station	Kohat	Time of taking off	. 0850 hrs.
Squadron	27 (B)	Time of maximum height	0930 „
Date	12-8-33	Time of landing	1005 „

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks.
0	85	78	75	Sky heavily covered with detached Cu. at dawn—cloud decreasing in forenoon—partially covered with A Cu and Cu. in afternoon—clearing gradually in evening. Readings were taken inside Cu cloud, which appeared to be melting or in a "steady" state, base at 2,500 feet, thickness 600 feet The dry bulb was lower inside than outside at the base of the cloud, but the same at the top. The wet bulb was higher inside than outside High lapse-rate from ground to 1,000 feet Lapse-rate in cloud was less than the saturated adiabatic
10	80	75	80	
20	77	74	86	
25	76 (75)	73 (75)	88 (100)	
30	74 (74)	71 (74)	88 (100)	
35	73	70	88	
40	71	68	86	
50	67	64	87	
60	62	58	80	
70	59	55	80	
80	56	51	76	
90	53	47	70	
100	50	44	69	
110	47	41	68	
120	43·5	38·5	70	
130	41	38	81	
140	39	36	81	
150	36	33	79	

TABLE I—*contd.*

Station ..	Risalpur	Time of taking off .	0910 hrs.
Squadron	39 (B)	Time of maximum height .	0940 „
Date	27-8-33	Time of landing	1005 „

Height above ground. ft. (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	78		75		87		Sky heavily covered with A St, A. Cu., and St Cu at first (rain observed in vicinity)—clouds decreasing in forenoon—sky partially covered with A St A Cu, and Fr Cu at midday—moderately covered with Ci Cu and A. Cu in afternoon and evening—clear at night
10	73		71		92		Pilot reported slight 'bumpiness' near ground and from 7,000 feet to 10,000 feet
20	70	(68)	69	(68)	96	(100)	Readings were taken inside melting St Cu cloud, base at 2,000 feet, thickness 800 feet Observations were also made inside but not outside A St cloud, base at 12,900 feet, thickness over 2,000 feet
25	69	(67)	67 5	(67)	94	(100)	The dry bulb was lower inside the strato-cumulus cloud than outside The wet bulb inside was lower at the base but the same as outside at the top There was a high lapse-rate from the ground to 1,000 feet but a low lapse-rate inside both the strato-cumulus and alto-stratus cloud. The humidity inside the cloud at 2,800 feet was less than 100%
28	68	(67)	66	(66)	92	(96)	
30	68		66		92		
40	67		63		83		
50	65		60		77		
60	63		58		67		
70	62		54		63		
80	57		50		64		
90	51		45		70		
100	45 5		42 5		85		
110	41		39		89		
120	38		37		90		
130	(35)		(35)		(100)		
140	(33)		(33)		(100)		
150	(32)		(32)		(100)		

Station ..	Kohat	Time of taking off	0940 hrs
Squadron .	60 (B)	Time of maximum height	1020 „
Date ..	30-8 33	Time of landing	1055 „

Height above ground ft (hundreds)	Dry Bulb °F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks.
0	81		77		83		Sky partially covered with Cu in early morning—cloud decreasing in forenoon—sky moderately covered with Cu at midday—partially covered with Cu. in afternoon—clearing in evening
10	76		70		76		Pilot reported slight 'bumpiness' from ground to 1,000 feet
20	73		67		74		Readings were taken in melting cumulus cloud, base at 4,500 feet, thickness 600 feet.
30	69		65		82		The dry bulb was the same inside and outside at the base of the cloud but lower inside, at the top The wet bulb was higher inside. The lapse-rate was high from ground to 1,000 feet, but less than the saturated adiabatic inside the cloud. The humidity was less than 100% at the base of the cloud.
40	66		63		86		
45	65	(65)	62	(64)	86	(95)	
50	64	(63)	62	(63)	91	(100)	
51	64	(63)	61	(63)	87	(100)	
60	61		55		71		
70	57		50		65		
80	53		45		58		
90	49		42		63		
100	45 5		39 5		65		
110	42		38		75		
120	39		35		75		
130	36		33		79		
140	33 5		31		82		
150	31		29		83		

TABLE I—*contd.*

Station ..	Kohat.	Time of taking off	0945 hrs
Squadron	60 (B)	Time of maximum height	1030 „
Date ..	.. 31-8-33.	Time of landing .. .	1115 „

Height above ground ft. (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	79	76	87	Sky moderately covered with Cu in early morning, clearing almost completely in forenoon, but partially covered with Ci Cu and A Cu in afternoon—clearing in evening Readings were taken inside melting cumulus cloud, base at 3,800 feet, thickness 500 feet The dry bulb was lower inside than outside the cloud except at the base where it was the same The wet bulb was higher inside The lapse-rate was high from ground to 1,000 feet and greater than the saturated adiabatic inside the cloud The wet bulb at 4,000 feet in the cloud was 1·0° higher than the dry bulb
10	74	70	84	
20	70	66·5	85	
30	67	64	86	
38	65 (65)	62 (65)	87 (100)	
40	64 (63)	62 (64)	92 (100)	
43	63 (62)	61 (63)	92 (100)	
50	61	59	90	
60	58	55	84	
70	55	46	54	
80	52	42	47	
90	50	39	44	
100	48	36	37	
110	44	31	26	
120	41	31	41	
130	37	29	48	
140	32·5	27	59	
150	29	26	73	

Station ..	Kohat	Time of taking off	0730 hrs
Squadron	27 (B).	Time of maximum height	0815 „
Date ..	9-9-33	Time of landing	0850 „

Height above ground ft (hundreds).	Dry Bulb °F	Wet Bulb °F.	Humidity per cent	Weather conditions and remarks
0	74	70	82	Sky lightly covered with Cu cloud at first—becoming partially covered with Cu, A Cu, and C towards midday—cloud decreasing in afternoon—sky lightly covered in evening with Ci Cu and A Cu Pilot reported slight 'bumpiness' from 6,000 feet to 7,000 feet Readings were taken inside growing cumulus cloud, base at 7,100 feet, thickness 500 feet The dry bulb was the same inside and outside the base of the cloud but lower inside at the top The wet bulb was higher inside High lapse-rate from 2,000 to 4,000 feet and from 6,000 feet to base of cloud Lapse-rate in cloud greater than saturated adiabatic. Stable layer existed above top of cloud Humidity in cloud less than 100 per cent. at 6,500 feet.
10	72	65	71	
20	69	62	70	
30	64	58	72	
40	59	54	75	
50	56	52	77	
60	53	49	77	
70	48	45	82	
71	48 (48)	45 (48)	82 (100)	
75	46 (45)	42 (44·5)	75 (97)	
80	45	39	63	
90	43	36	58	
100	41	34	57	
110	38	32	59	
120	35	29	58	
130	32	27	62	
140	29	25	66	
150	26	24	79	

TABLE I—*contd.*

Station ..	Kohat	Time of taking off	0930 hrs.
Squadron	27 (B)	Time of maximum height	1015 „
Date ..	10-9-33	Time of landing	1050 „

Height above ground ft (hundreds)	Dry Bulb °F.	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	82	72	62	Sky heavily covered with A Cu and Cu in early morning—cloud decreasing in forenoon—sky lightly covered with A Cu at midday, clearing in afternoon—clear rest of day Readings were taken inside melting Cu cloud, base at 8,800 feet, thickness 600 feet Dry bulb was lower inside than outside the cloud The wet bulb was the same inside and outside except at base of cloud where it was higher inside High lapse-rate from 3,000 feet to 5,000 feet Lapse-rate in cloud mainly greater than the saturated adiabatic Stable layer at top of cloud.
10	78	65	50	
20	75	62	49	
30	72	62	59	
40	67	59	67	
50	62	56	71	
60	59	55	80	
70	56	53	84	
80	51	49	87	
88	48 (47)	46 (47)	91 (100)	
90	48 (46)	46 (46)	91 (100)	
94	47 (45)	45 (45)	91 (100)	
100	46	44	88	
110	44	41	81	
120	41	37	75	
130	37	33	73	
140	32	30	84	
150	27	26	88	

Station	Peshawar	Time of taking off	1010 hrs
Squadron	20 (A C)	Time of maximum height	1045 „
Date ..	17-9-33	Time of landing	1110 „

Height above ground ft (hundreds)	Dry Bulb °F	Wet Bulb °F	Humidity per cent	Weather conditions and remarks
0	85	76	66	Sky partially covered with Cu and A Cu in early morning—A Cu clearing a little in forenoon but Cu and Cu Nb developing over hills—sky heavily covered in afternoon and mainly overcast in evening with Ci St, Cu Nb, and Cu—dust-storm and squally winds followed by thunderstorm—further thunderstorms at night Pilot reported considerable 'bumpiness' from ground to 1,000 feet Readings were taken in growing Cu cloud, base at 8,800 feet, thickness 900 feet The dry bulb was the same inside and outside the cloud but the wet bulb was higher inside Superadiabatic lapse-rate from ground to 1,000 feet and from 6,000 feet to 7,000 feet Lapse-rate in cloud greater than the saturated adiabatic Stable layer at top of cloud Humidity was less than 100 per cent in the cloud except at 9,000 feet.
10	76	68	68	
20	76	68	68	
30	72	65	71	
40	68	61	68	
50	66	60	73	
60	62	56	72	
70	56	51	74	
80	55	51	78	
88	51 (51)	48 (50)	86 (96)	
90	50 (50)	48 (49)	91 (96)	
95	48 (48)	46 (48)	91 (100)	
97	47 (47)	45 (46)	91 (97)	
100	47	44	85	
110	45	36 5	52	
120	42	34	52	
130	38	32	60	
140	34 5	31	74	
150	31	30	90	

TABLE I—*concld.*

Station	. Risalpur	Time of taking off	0730 hrs.
Squadron	11 (B)	Time of maximum height	0305 „
Date	. 23-9-33	Time of landing	0835 „

Height above ground ft (hundreds)	Dry Bulb F		Wet Bulb F		Humidity per cent		Weather conditions and remarks.
0	80		71		65		Sky clear at dawn—becoming moderately covered with Cu in forenoon—cloud decreasing in afternoon—clear in evening and at night. Readings were taken inside growing Cu. cloud, base at 7,000 feet, thickness 900 feet. The dry bulb was lower inside the cloud than outside but the wet bulb was higher inside. High lapse-rate from 4,000 feet to 5,000 feet, below cloud. Lapse rate inside cloud greater than saturated adiabatic. Humidity less than 100 per cent at base of cloud.
10	78		69		64		
20	76		67		64		
30	74		65		63		
40	71		63		68		
50	66		60		73		
60	62		58		80		
70	58	(57)	54	(56)	80	(95)	
75	55	(54)	51	(54)	78	(100)	
79	53	(51)	49	(51)	78	(100)	
80	53		49		78		
90	50		46		78		
100	47		39		57		
110	43		35		54		
120	38		31		55		
130	34		29		64		
140	29		25		65		
150	26		23		70		

Station	.. Risalpur	Time of taking off	0650 hrs
Squadron	.. 39 (B)	Time of maximum height	. 0730 „
Date	29 9 33	Time of landing	0805 „

Height above ground ft (hundreds)	Dry Bulb F		Wet Bulb °F		Humidity per cent		Weather conditions and remarks
0	77		72		79		Sky lightly covered with Cu in early morning—cloud decreasing in forenoon—clear after midday. Readings were taken inside melting Cu cloud, base at 8,100 feet, thickness 200 feet. The dry bulb was lower but the wet bulb higher inside than outside the cloud. Superadiabatic lapse rate from 5,000 feet to 7,000 feet—below cloud.
10	78		69		64		
20	77		69		69		
30	74		67		71		
40	70		64		75		
50	67		62		78		
60	62		58		80		
70	56·5		54·5		89		
80	52		51		95		
82·5	51	(50)	49	(50)	88	(100)	
90	48		44		76		
100	45		40		71		
110	42		36		63		
120	40		34		64		
130	36·5		30·5		59		
140	32		27		61		
150	28		24		64		

TABLE II.—*Observations made at Thandiani—8,800 ft. m.s.l*

Date	Time hrs	Readings taken at X_1			Readings taken at X_2			Differences ($X_1—X_2$)			Weather conditions and remarks
		Dry °F	Wet F	Humidity %	Dry °F	Wet °F	Humidity %	Dry F	Wet. °F	Humidity. %	
15 8 33	1000	59.7*	58.9*	96*	59.8	57.0	86	−0.1	−1.9	−10	*Cloud melting*—Variable sky in morning (Cu cloud) after rain at night—clearing during day. Moderate winds with slight turbulence. Thickness of cloud about 600 ft
17 8 33	1030	62.6	61.6	95	62.3	61.3	95	−0.3	−0.3	0	*Cloud growing*—Sky moderately covered with Fr Cu in morning and afternoon—Clearing at night. Fresh winds with slight turbulence. Thickness of cloud about 400 ft
22 8 33	1630	60.9*	60.3*	97*	61.0	60.1	95	−0.1	+0.2	+2	*Cloud melting*—Overcast with Cu, Nb and showering in morning—variable sky (Cu cloud) in afternoon. Clearing in evening. Light winds with small downward component. Thickness about 800 ft
26 8 33	1200	64.2*	64.2*	100*	63.1	62.5	97	−1.1	+1.7	+3	*Cloud growing*—Sky lightly covered with Cu at first—becoming mainly overcast with Cu, Nb during day—thunderstorm in evening. Light winds with marked upward component. Thickness about 3,000 ft
28 8 33	0930	64.0	60.4	83	63.4	59.5	81	+0.6	−0.9	+2	*Cloud growing*—Sky lightly covered with Fr Cu all day—Clear at night. Light winds—very little turbulence. Thickness of cloud about 200 ft
2 9 33	1130	59.1*	59.4*	100*	58.7	58.0	96	−0.4	1.4	−4	*Cloud growing*—Sky moderately covered with Cu in morning—heavily covered with Cu and Cu Nb in afternoon and evening. Moderate winds, marked ascending currents. Thickness about 1,500 ft
3 9 33	1730	60.2	59.2	95	59.7	56.2	82	+0.5	−3.0	+13	*Cloud growing*—Sky clear at first, becoming lightly covered with Cu in morning and partially covered in afternoon and evening—cloudy at night. Light winds, much turbulence. Thickness about 2,000 ft
4.9 33	Not noted	62.2	60.8	93	62.2	58.8	83	0	−2.0	+10	*Cloud melting*—Sky moderately covered with Cu in morning and early afternoon—clearing in evening. Light winds with very little turbulence. Thickness of cloud about 500 ft
6 9 33	1730	57.6	56.1	92	58.1	56.0	89	−0.5	0.1	−3	*Cloud melting*—Sky clear at first, lightly covered with Cu in forenoon and afternoon—Clearing in evening. Light winds with marked downward component. Thickness of cloud about 300 ft

*Readings taken in cloud.

M46DGofOb—380—1-8-35—GIPS

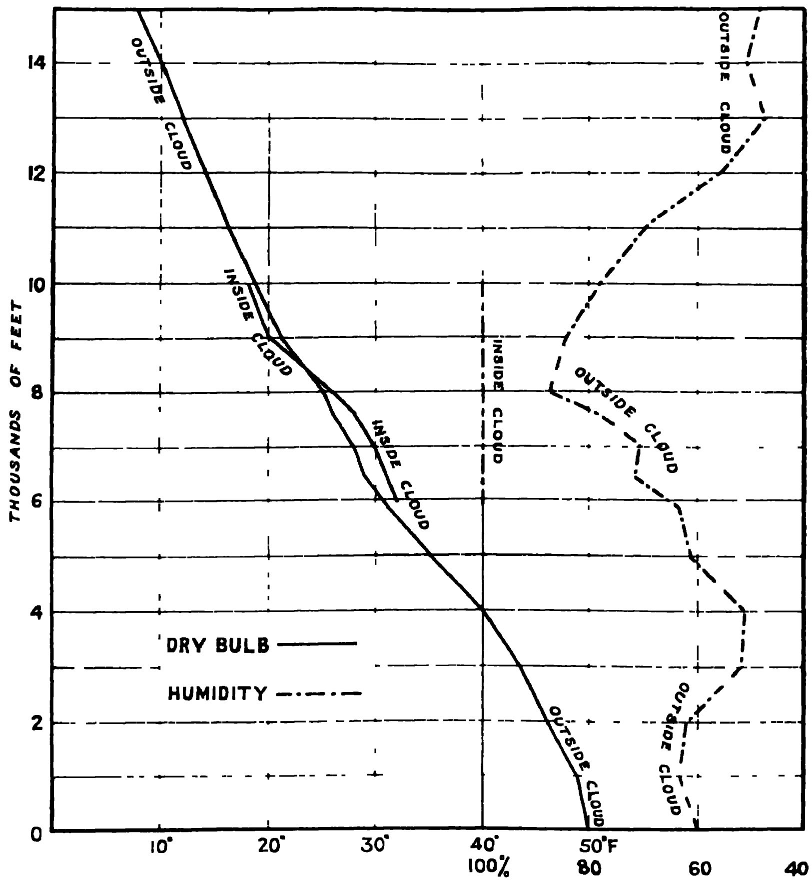


FIG I. CLOUD IN GROWING STATE
AT KOHAT ON 15-2-1933.

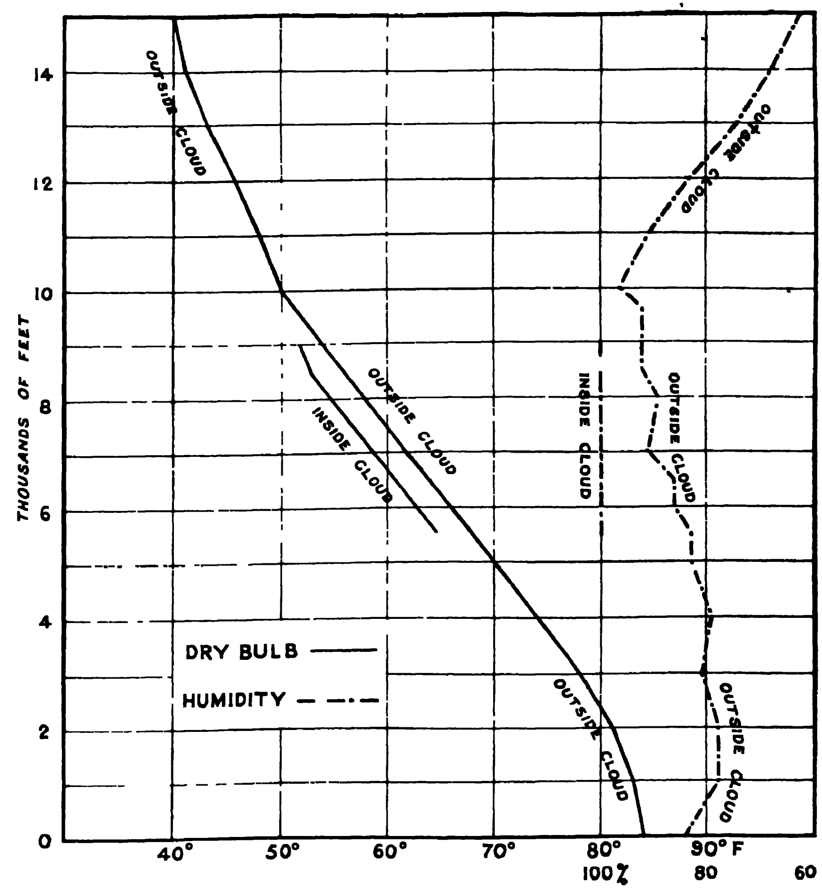


FIG. 2 CLOUD IN STEADY OR DECAYING STATE
AT RISALPUR ON 12 - 7 - 1933

(6) G P Z O Poona, 1935

TABLE II.—*Observations made at Thandiani—8,800 ft. m.s.l.*

NO—SN6/62

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The Distribution of Temperature in the Upper Levels of a Depression originating in the Bay of Bengal during the Indian Southwest Monsoon

BY

N. K. Sur.

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THE DISTRIBUTION OF TEMPERATURE IN THE UPPER LEVELS OF A DEPRESSION ORIGINATING IN THE BAY OF BENGAL DURING THE INDIAN SOUTHWEST MONSOON

BY

N K SUR

(*Received on 12th September 1934*)

Abstract - During the period of activity of the southwest monsoon some depressions originate in the Bay of Bengal preceded by a well-marked fall of pressure in Burma These generally move in a northwesterly direction through the central parts of India and reach the neighbourhood of Rajputana Sounding balloon ascents at Agra, when one such depression was passing through Rajputana, show that the upper levels of air in its outer regions were characterised by temperatures lower than the normal values for the corresponding heights in the monsoon season The level of tropopause above the depression was also found to be lowered

In a previous paper[1], it has been shown that air-masses which take part in a storm or depression originating in the north Bay of Bengal during the period of activity of the southwest monsoon are made of the southwesterly winds from the Arabian Sea, traversing the central and southern parts of India, and the easterly winds deflected from the hills of the Chittagong Arakan coast, and sweeping over the Gangetic valley The dry northwesterly continental air, which is generally confined to northwest India, in the neighbourhood of the Punjab and north Rajputana, affects the depressions only when they reach Rajputana after coursing through Orissa, the Central Provinces and Central India. Some physical characteristics of such depressions, as far as could be inferred from the available data, have been discussed before[2].

A few storms or depressions which form at the head of the Bay of Bengal near the Orissa or Burma coasts are preceded by a well-marked decrease of pressure over the mainland of Burma and the adjacent seas. Good examples of a series of such depressions may be seen on reference to the Indian Daily Weather Reports of August

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[1] N. K. Sur—On the Physical Characteristics of Fronts during the Indian Southwest Monsoon Memoirs of the Ind. Met. Dept., Vol. 26, Part III, pp. 37—50, 1933.

[2] N. K. Sur—*Loc. Cit.*

TABLE I.

gkm.	26-8-29 Temp. (°A)	27-8-29 Temp (°A)	Normal Temp for Aug (°A)	26-8-29 Pressure (mb)	27-8-29 Pressure (mb)	Normal Pressure for Aug (mb.)	No. of observations for normals.
0·17 (Surface)	299·5	300·0	303	980	984	981	33
1	291·3	292·4	297	888	893	891	32
2	287·6	288·2	291	788	792	792	32
3	284·2	285·2	286	698	702	702	32
4	280·0	280·1	281	616	620	622	31
5	275·6	274·1	276	545	547	549	30
6	270·4	268·8	272	480	481	483	30
7	264·8	264·2	266	420	422	424	29
8	258·5	257·4	260	368	369	372	27
9	250·6	249·6	252	321	322	325	26
10	241·5	241·4	246	279	279	282	25
11	233·3	233·1	237	241	241	244	22
12	224·2	226·8	229	207	207	211	21
13	214·7	218·3	220	177	177	180	20
14	202·2	211·0	211	149	151	153	20
15	193·4	203·1	202	126	127	129	18
16	197·3	193·7	195	105	107	108	16
17	206·3	193·9	193	88	89	90	14
18	210·2	199·5	197	75	75	76	13

On 26th August 1929, temperatures up to 3 gkm were distinctly below normal. Between 4- 9 gkm though the temperatures were below normal, the difference was only of the order of 1°A or less, except at 6 gkm where it was slightly more. The presence of high and middle clouds[6] might have counterbalanced the fall of temperature which may have been otherwise more marked at these levels For 10—15 gkm levels the difference increased, the temperature being markedly below normal, whereas for 16-18 gkm levels the temperatures were higher than the normal.

Next day when the intensity of the depression diminished, the values of temperatures from ground to 15 gkm. increased as compared with the previous day, except between 5—9 gkm where a further slight decrease is noticeable. This decrease in temperature on 27th August 1929 may correspond to the decrease in amount of middle and high clouds as compared to that on 26th August 1929.

[6]These could not be directly observed on 26th August 1929 due to the sky being practically overcast with low clouds throughout the whole day, but on 27th August 1929 middle clouds could be observed before the time when the meteorograph was let off. The sky was almost clear by 22 hrs. I. S. T. but low clouds appeared again afterwards.

TABLE I.

gkm.	26-8-29 Temp. (°A.)	27-8-29 Temp (°A)	Normal Temp for Aug (°A)	26-8-29 Pressure (mb)	27-8-29 Pressure (mb.)	Normal Pressure for Aug. (mb.)	No. of observations for normals.
0·17 (Surface)	299·5	300·0	303	980	984	981	33
1	291·3	292·4	297	888	893	891	32
2	287·6	288·2	291	788	792	792	32
3	284·2	285·2	286	698	702	702	32
4	280·0	280·1	281	616	620	622	31
5	275·6	274·1	276	545	547	549	30
6	270·4	268·8	272	480	481	483	30
7	264·8	264·2	266	420	422	424	29
8	258·5	257·4	260	368	369	372	27
9	250·6	249·6	252	321	322	325	26
10	241·5	241·4	246	279	279	282	25
11	233·3	233·1	237	241	241	244	22
12	224·2	226·8	229	207	207	211	21
13	214·7	218·3	220	177	177	180	20
14	202·2	211·0	211	149	151	153	20
15	193·4	203·1	202	126	127	129	18
16	197·3	193·7	195	105	107	108	16
17	206·3	193·9	193	88	89	90	14
18	210·2	199·5	197	75	75	76	13

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In the height-temperature diagram corresponding to the sounding on 26th August, the most striking part is the isothermal region between the levels of 15210 and 15710 geodynamic metres, the temperature being 191°·7A and 192°A respectively at these heights. The undisturbed types of transition from troposphere to stratosphere in the monsoon season is shown in the inset (*vide* height-temperature diagram for 4th August 1930 Portions of traces of ascent and descent curves for 26th and 27th August are also shown on an enlarged scale). The increase of temperature above the normal values between 16—18 gkm. on 26th August is also significant, though on 27th August it decreased to a marked degree, being only slightly higher than the normal at 17 and 18 gkm

The distinctly lower level[7] of the tropopause on 26th August 1929 is also remarkable, though the level is higher up the next day due to the lesser intensity of the depression.

The lowering of and the characteristic isothermal region at the tropopause on 26th August 1929 may have been caused by the sucking down of the lower stratosphere, and the divergence of air usually pictured to take place in the higher levels of a cyclone near the tropopause[8]. For according to the equation[9]

$$\frac{dT'}{dz} = \frac{Q'p'}{Qp}\left(\frac{dT}{dz} + \frac{Ag}{c_p}\right) - \frac{Ag}{c_p}$$

the final temperature-gradient $\frac{dT'}{dz}$ along the vertical may decrease in the upper diverging region of a cyclone below the tropopause, where Q' Q and $p'<p$ and result in an isothermal region provided the effect of $\frac{Q'}{Q}>1$ outweighs that of $\frac{p'}{p}<1$ For the region in the neighbourhood of the tropopause, where the lower stratosphere is sucked downwards, $p'>p$, and if there is also divergence of air of the lower stratosphere after being drawn downwards (see the figure given by Palmen), $Q'>Q$ thus the effect on the temperature gradient along the vertical will be more marked, and an isothermal region or even a region of inversion may result The marked rise of temperature between 16—18 gkm. indicates a strong probability of heating near the tropopause either by descent of air alone or both by descent and divergence

Evidence regarding the decrease in temperatures and the lower level of the tropopause has been obtained when the depression was moving through Rajputana, where the drier northwesterly winds are known to take part in a depression of the monsoon season It cannot however be emphasised that these features will be necessarily found when a monsoon depression or storm is over the Bay of Bengal or has just entered the mainland of India. Data regarding the distribution of temperature and humidity in such a depression at or near its place of origin are still lacking.

I wish to record here my best thanks to Messrs. J. C. Roy and Brij Mohan of the Upper Air Observatory, Agra, for help in preparing the diagrams and to Mr. G. Chatterjee, Meteorologist-in-charge, for placing the sounding balloon records at my disposal.

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[7]The mean level of the tropopause in August lies between 16—17 gkm.

[8]*Vide e.g.* E. Palmen, Beziehg-Zwisch Troposphar. U. Stratosphar. Temperature-u Luftdruck-schwankungen. Beitr. Phys fr. Atm. Band 17, Heft 2, S. 105, Fig. 1, 1931, or A. Refsdal, Zur Thermodynamic der Atmosphare, Geofysiske Publikasjoner, Vol. IX, No. 12, p. 55, fig. 12, 1932.

[9]See Exner's Dynamische Meteorologie, Second edition 1925, p. 85, for the meaning of the symbols used.

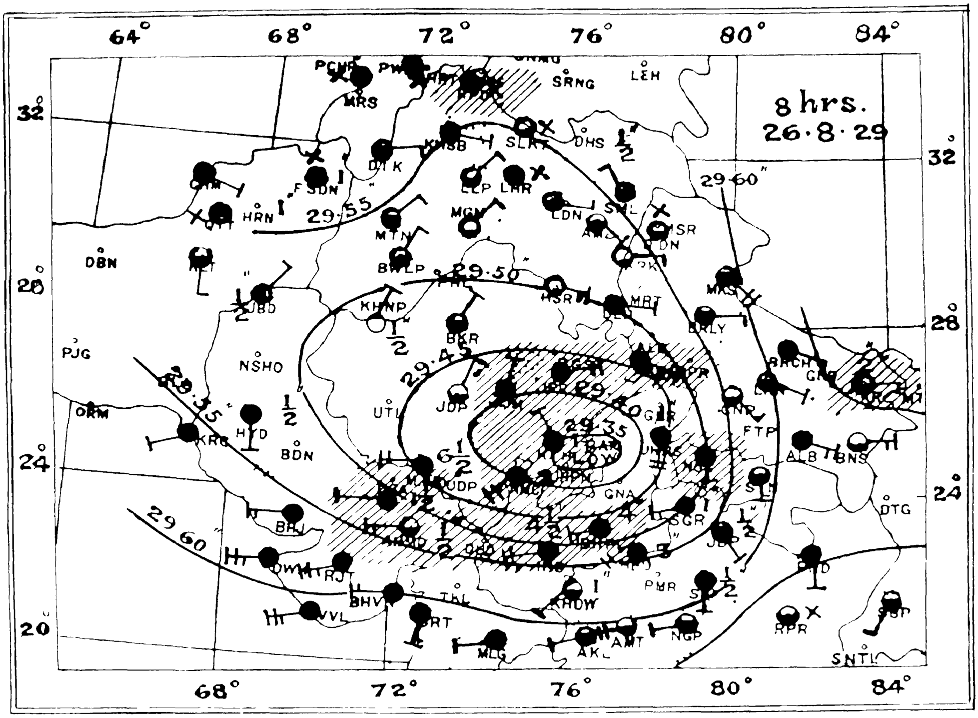
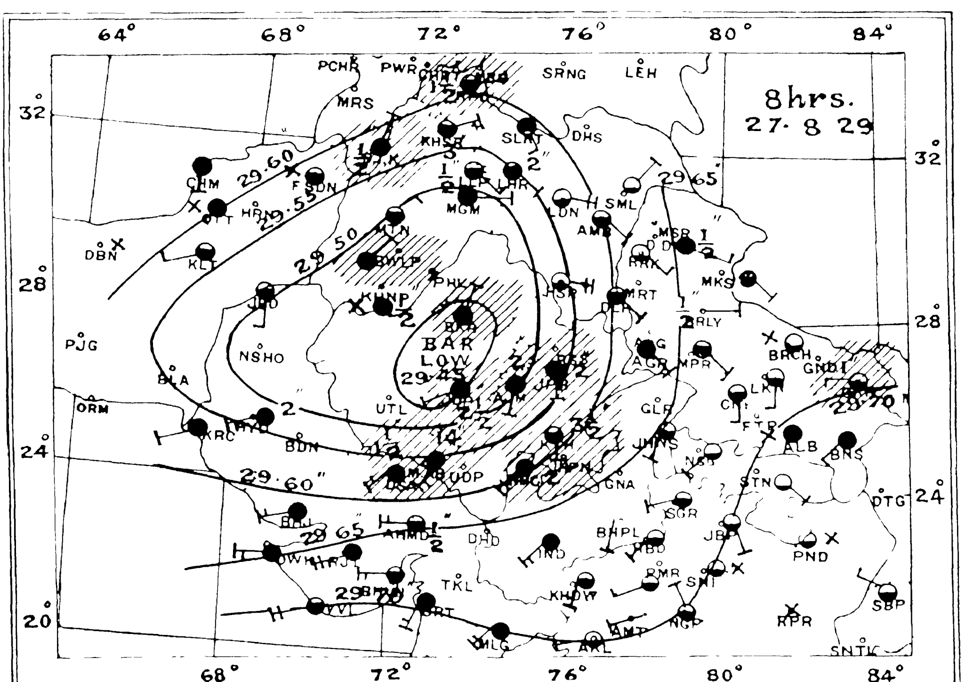


Fig. 1



G P I O POONA, 1934

Fig 2

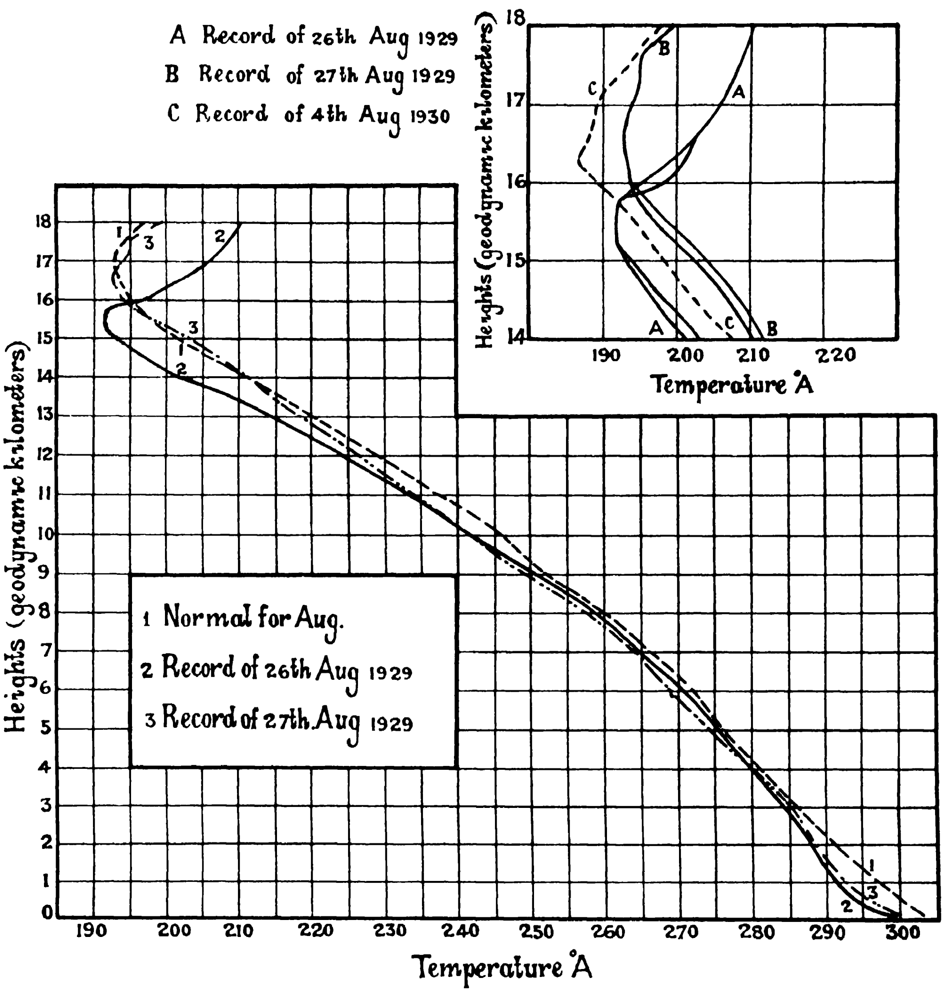

A Record of 26th Aug 1929
B Record of 27th Aug 1929
C Record of 4th Aug 1930
Heights (geodynamic kilometers)
Temperature °A
1 Normal for Aug.
2 Record of 26th Aug 1929
3 Record of 27th Aug 1929
Heights (geodynamic kilometers)
Temperature °A

Fig. 3

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INDIA METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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Evaporation in India calculated from other Meteorological Factors

BY

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(VOLUME VI.) **Number 61.**

EVAPORATION IN INDIA CALCULATED FROM OTHER METEOROLOGICAL FACTORS*

BY

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(*Received on 24th February 1934.*)

Abstract.—The paper contains a discussion of the mean monthly and annual evaporation at 80 stations in India. The evaporation is calculated from the formula.

$E = (1 \cdot 465 - 0 \cdot 0186\, B)(0 \cdot 44 + 0 \cdot 118\, W)\left(\frac{100}{h} - 1\right) e$, where E is the mean daily evaporation in inches, B the barometric pressure at station level in inches, W the mean wind velocity of the day at 4 feet above ground in miles per hour, h the mean relative humidity and e the vapour pressure in inches of mercury. Monthly and annual evaporation charts have been drawn and discussed. The values of "rainfall minus evaporation" at the 80 stations have been calculated; these indicate the arid and the wet zones of the country. Finally, the importance of evaporation in salt-works and its influence on plant life have been discussed.

CONTENTS.

1. Introduction.—It is well known that evaporation has a very important bearing on agriculture as it is one of the major factors in the disposal of water in the upper layers of the soil, received mainly in the form of rainfall or, to a smaller extent, as irrigation. Further, the conditions which control evaporation also influence the transpiration of water by plants; this is again one of the major factors in the disposal of soil moisture. A knowledge of the evaporating power of the atmosphere is also of primary interest to the irrigation and the water works engineer, as well as to persons controlling salt works. To the meteorologist the phenomenon of evaporation has a special appeal as all the moisture in the atmosphere which is his 'working substance' is derived ultimately by evaporation from the oceanic surfaces, the great lakes and rivers, the soil and the plant world.

* This investigation was made in the Agricultural Meteorology Branch (India Meteorological Department) financed by the Imperial Council of Agricultural Research.

It is surprising therefore, that actual records of evaporation in various parts of the world are extremely scanty and mostly unsuitable for a comparative study. Both in the length of the records and in the apparatus used for the measurement there is considerable variation; one may say that, barring a few exceptions, the subject has attracted only amateur attention. Systematic measurements have been started recently in the United States of America. Egypt, Japan and other countries are also slowly following.

In India there are about 3,000 raingauge stations, distributed more or less uniformly. The records of these stations are available generally for more than 40 or 50 years. Compared with this rainfall organisation, the attempts at measuring evaporation have been quite meagre, perhaps in view of the difficulties of installing suitable instruments and of taking observations with them. Some observations spread over a few years are available from the old records of the Trivandrum and Madras observatories. The observations of Leather[1] at Pusa, those made at a few irrigation works on the Cauvery and at some of the agricultural stations in the Punjab and in Sind, and the very detailed observations made at Colaba and discussed by S. K. Banerji and H. M. Wadia in a recent Memoir of the India Meteorological Department[2], practically exhaust the scanty list of data available in India. The importance of commencing observations of evaporation at a large number of representative stations in India on a uniform basis, with similar instruments and similar exposures and precautions, can hardly be over-emphasized. In the absence of such records and in order to obtain a preliminary idea of evaporation in India, an attempt has been made in the present paper to study the subject as far as possible from the meteorological factors which directly control it.

2 **Evaporation Formulæ.**—Investigations in the laboratory and outside have shown that evaporation increases with (*a*) the defect of saturation of water vapour, (*b*) the velocity of the wind, (*c*) the temperature of the water surface, and (*d*) the temperature of the air just above the water surface. The effect of atmospheric pressure, as judged from simultaneous observations at a few stations at different altitudes, has been found to be to suppress evaporation with increase of air pressure and *vice versa*.

Some of the more important empirical formulæ* suggested by different workers for calculating evaporation from meteorological factors are given in the *Table* below :—

TABLE 1.

Serial No.	Formula.	Name of worker.	Nature of apparatus.
1.	$E=(0\cdot40+0\cdot199W)(e_s-e_d)$	Fitzgerald ..	Observations under controlled conditions inside laboratory as well as under natural conditions outside.
2.	$E=(0\cdot39+0\cdot187\,W)(e_s-e_d)$	Carpenter .	Experiments on a sunken tank 3 feet square.
3.	$E=(1\cdot96\,e_w+43\cdot88)(e_w-e\ )$	Russel ..	Observations from Piche evaporimetres at 19 Weather Bureau stations in the U. S. of America.
4.	$E=(0\cdot8424+0\cdot01056W)\times(e_s-e_d)$	Stelling .	Based on pan experiments in Russia (in metric units)
5.	$E=0\cdot138\,\frac{e_s}{e_d}\times\frac{d_e}{d_s}(1+0\cdot07\,W)$ W in kilometers per hour.	Bigelow ..	Based on very exhaustive and complete experimental data.
6.	$E=C\,(\psi e_s-e_d)$	Horton ..	Theoretical study and results of observations.
7.	$E=(0\cdot5+0\cdot05W)(e_s-e_d)$	Meyer and Freeman.	Based on Weather Bureau Observations, U. S. A.

* C. Rohwer. *Loc. Cit.*

8. $E=\frac{H-S-C}{L(1+R)}$	Cumming and Richardson.	Based on the theory that evaporation is a function of insolation
9. $E=(e_s-e_d)\times[0\cdot319+0\cdot335\,(W-10\cdot8)]$	Folse	Based on statistical study of the gauge heights of Lake Superior, Lake Michigan and Lake Huron.
10. $E=2\cdot0(\log t-1\cdot74)+0\cdot33(\log D-1\cdot00)+0\cdot36(\log W-0\cdot125)$	Leather	Based on the evaporation data collected at Pusa (E and W in metric units)
11. $E=(1\cdot465-0\cdot0186B)\times(0\cdot44+0\cdot118\,W)\,(e_s-e_d)$	Carl Rohwer	Based on very exhaustive and complete studies in laboratory and outside

The symbols used above are explained below :—

E = evaporation in inches per 24 hours (or in mms per 24 hrs where metric units are used)

t = mean temperature of atmosphere in °F

e_s = mean vapour pressure of saturated air at the temperature of the water surface in inches of mercury (or in mm. when metric units are indicated)

e_d = mean vapour pressure of saturated air at the temperature of the dew point, in inches of mercury (or in mm. where metric units are indicated)

e_w = vapour pressure at the mean wet bulb temperature, in inches of mercury (or in mm where metric units are indicated)

C = coefficient of the function

D = 100 — 8 A M humidity.

W = mean velocity of groundwind in miles per hour (or metres per second where metric units are indicated)

B = mean barometer reading, in inches of mercury.

$\frac{d_s}{d_\theta}$ = rate of change in the maximum vapour pressure with temperature

H = net radiation

S = heat stored in a column of water of unit cross-section.

L = latent heat of water.

R = Bowen's ratio

ψ = wind factor

The formula No. 11 in the table has been obtained by C. Rohwer[3] from a series of elaborate experiments intended to estimate separately the influence of each of the factors at a time, by keeping the others unchanged. Thus the variation of evaporation with (1) temperature of the water surface, (2) temperature of the air near the evaporating surface, (3) the defect of saturation, (4) wind velocity near the evaporating surface, and (5) altitude of observing station above mean sea level have been carefully estimated, by the series of experiments.

The formula has been tested with comparative observations taken with the following types of evaporimeters and found to be satisfactory

(1) U. S. A. Weather Bureau land pan 4 ft in diameter, 10″ deep, supported on a grillage of timbers with top of tank 14″ above the ground surface.

(2) Colorado pan, 3 ft. square, 18″ deep, sunk in ground with top edge 1¾″ above ground.

(3) 4 ft. circular sunken pan, 3 ft. deep with rim 3″ above ground, and

(4) a circular pan, 4 ft. in diameter and 10″ deep floating in water.

Simultaneous observations taken from a large reservoir about 1,800 acres in extent indicate that the formula gives values about 30 per cent. higher.

The values of evaporation computed from the formula 11 have also been found to agree fairly closely with actual measurements at a large number of stations in the U. S. A under natural conditions *

3. Calculation of possible evaporation in India from Meteorological factors.—It was accordingly considered desirable to calculate from this formula (11) the mean monthly evaporation expressed as inches per day and per month at representative stations in India for the twelve months of the year *Plate III* shows the 80 stations selected for calculating evaporation The height of anemometer cups above ground level at each station is given against the station circle In selecting the stations the quality of exposure of the wind instruments was given primary consideration, stations with the best exposure have been selected The monthly normals of the following elements are available for these stations -

(*a*) Barometric pressure at 8 A M (local time) and reduced to 32°F.

(*b*) Mean wind velocity in miles per hour.

(*c*) The percentage humidity at 8 A.M. (local time), and

(*d*) Vapour pressure in inches of mercury at 8 A M. (local time).

The effect of the correction for converting (*a*) into the daily mean is negligible.

The wind instruments are usually exposed at the top of a building, or tower, in order to secure as free an exposure as possible The exposures, as well as the height of the instruments above ground, vary considerably from place to place The variation of wind with height has been studied by Captain E. H Chapman [4] *Fig 1* gives the ratio of wind at any height to that at standard level of 4 feet as calculated from the data discussed by Chapman. By using the reduction factor obtained from *Fig 1*, the mean wind velocities for all the stations and for different months were reduced to standard level of 4 feet, which is the height of the base of a Stevenson screen. This height was chosen because the temperature and humidity data refer to this level and because we have no knowledge at present of the correction for reducing them to any lower level

The humidity and vapour pressure are determined from the readings of the dry and wet bulb thermometers taken at 8 A.M. It is well known that the percentage humidity is extremely variable from hour to hour, the variations of vapour pressure from hour to hour are small, but are not quite negligible. These variations of course change with season and with place and our knowledge of them is confined to about 24 stations in India, where hourly observations of the various meteorological elements were collected for a few years These have been discussed by Eliot[5] For the remaining stations the corrections were applied by selecting appropriate combinations of the corrections of the above stations.

The mean pressure, wind velocity reduced to 4 feet, humidity and vapour pressure reduced to mean of day for the 12 months of the year are given in the first four columns of *Table 2.*

Modification of Formula No. 11 of Table 1.—C. Rohwer's expression for evaporation is:

$$E=(1\cdot465-0\cdot0186\,B)\,(0\cdot44+0\cdot118\,W)\,(e_s-e_d).$$

We have no data of water surface temperatures at these stations and therefore have no means of directly calculating e_s. Since, however, we are concerned with the mean daily evaporation, we may assume that the mean daily temperature of a water surface will not differ materially from that of the air at the same level.

On the above assumption $e_s-e_d=(\frac{100}{h}-1)\,e$, where h is the humidity percentage and e is the vapour pressure as given in *Table 2.*

* C. Rohwer, *Loc. Cit.*

The mean daily evaporation for the different months and stations were calculated from the modified formula :

$$E=(1\cdot465-0\cdot0186\ B)\ (0\cdot44+0\cdot118\ W)\ (\frac{100}{h}-1)\ e \qquad (12).$$

In view of the fact that the daily means of the meteorological factors have been used for calculating evaporation, it may be expected that the values obtained will give fairly reasonable estimates of daily evaporation. Such information will surely prove instructive and useful until actual records are collected at a large number of stations.

It may be interesting to compare the available evaporation data recorded by individual workers at a few places in India for short periods and with widely different types of instruments with the values calculated from the meteorological factors according to formula 12. The comparisons of course suffer from two shortcomings, (a) the calculated values refer to results that would be obtained with a U. S. A. type of instrument under a standard exposure, and (b) the calculated values would represent the average conditions over a long period, whereas the values observed at the few stations refer to individual months or years.

The actual and calculated values are given in *Table 3*. Relevant details or remarks are also given as foot notes.

One finds if not perfect agreement of numerical values, at least agreement in the order of magnitude and in the general seasonal variations.

In *Table 2*, columns 5–7, are given for the sake of comparison, (a) the mean daily evaporation in inches, (b) the mean total evaporation of the month calculated at the daily rate and (c) the mean monthly rainfall. A point to be borne in mind is that the calculated evaporation really shows how much water may be expected to be evaporated per day if a vessel with water is exposed at 4 feet, *i.e.* what one might call " the evaporating power " of the atmosphere at that level.

The net contribution to a reservoir at 4 feet above ground due to " rainfall minus evaporation " in different months of the year and during the year as a whole is a very interesting factor which indicates how a reservoir freely exposed to rainfall but collecting no drained waters will lose or gain in water content, according to the nature of the locality and the season.

4. Discussion of Results.—The monthly and annual ' evaporation ' data for different stations have been plotted on charts and lines of equal evaporation drawn. These are given in *Figs. 13* to *25, Plates IV* to *VI*, for the different months and for the year as a whole.

The general features brought out by these charts are described below :—

January.—Evaporation over Bengal, Assam, Burma and the Indo-Gangetic valley is below 5" per month ; the lowest evaporation occurs in Assam, north Burma and the sub montane regions of the Himalayas. Higher rates of evaporation prevail over the Peninsula, excepting for a narrow belt below the Mysore plateau. The maximum evaporation occurs over the South Bombay Deccan, *e.g.*, Sholapur 16·1", Aurangabad 14·8".

February.—The evaporation in this month is practically similar to that in January. The ' high ' over Madras has merged into the ' high ' over the Deccan ; there is a slight fall over the Malabar coast and a slight increase over Tenasserim.

March.—All over the country there is an increase of evaporation, this being most marked over the Bombay Deccan and the central parts of the country including Rajputana and Orissa. The very low rate of evaporation over the interior of North-East India still persists.

April.—There is a further increase all over the country excepting South India and Lower Burma. The largest increase is over the Bombay Deccan, the monthly rate of evaporation being as high as 29·1″ at Aurangabad, 24·9″ at Sholapur and 24·3″ at Neemuch. The rate of evaporation increases also very rapidly as one approaches this "high" belt from the coast, *e.g.*, 8·5″ at Bombay, 17·7″ at Poona and 29·1″ at Aurangabad.

May.—The belt over which evaporation is higher than 15″ per month has increased very much in area; but the intensity of the 'high' over the Bombay Deccan has weakened somewhat under the influence, presumably, of the occasional thunderstorms that occur during this month The maximum evaporation area has also shifted northwards. Elsewhere the evaporation is on the increase except on the South Malabar coast and in Burma There is hardly any change in Assam, which continues to be the area of very low evaporation.

June.—With the onset of the South-West monsoon there is a general decrease in the rate of evaporation all over the Peninsula, Bengal, Burma and the Gangetic plain. Over Madras South-East, and North-West India, however, the influence of the monsoon winds or rain is feeble and the evaporation continues to be high. The area of maximum evaporation has now moved over to Sind and West Rajputana. The gradient from the interior to the sea-coast has also considerably weakened.

July.—There is a conspicuous fall of evaporation over the whole of Central India and a further slight fall over Burma and Malabar The region of high evaporation is confined to Sind and West Rajputana, *e g.*, Hyderabad (Sind) 17″.

August.—There is a further fall over Central India and North-West India. The comparatively high rate of evaporation over South-East Madras persists. The intensity of evaporation over Sind is less than in July.

September.—Very much like August.

October.—The area with evaporation 5″ and above shows an extension towards Bengal in comparison with September. The area of high evaporation is over Sind and Rajputana, but a tendency to move southwards is noticeable. A 'high' of small extent has also appeared over the Bombay Deccan. Another point of note is the fall of evaporation over South-East Madras with the setting in of the North-East monsoon conditions.

November.—The area of high evaporation over Sind and Rajputana has practically disappeared with wintry conditions setting in, but that over the Bombay Deccan persists. Lower Burma shows a tendency to rise.

December.—With the advance of winter the evaporation has fallen considerably over North India, the lowest evaporation now occuring over North Bengal, Assam and the sub-montane regions. Conditions are similar to January except that in January the 'high' over the Bombay Deccan is a little more intense. Secondary highs are also appearing over Madras South East, and the Northern Circars.

Annual.—As may be seen from the annual chart, Bombay Deccan, Rajputana and the western half of the Nizam's dominions have evaporation above 120″ per year. Assam and Upper Burma have the least evaporation with an annual value of the order of only 30″. Other areas have intermediate values. This chart may be compared with *Fig. 26, Plate VI*, showing the difference between rainfall and evaporation. In general, the west coasts of India and Burma which receive heavy rainfalls have slight evaporation. The arid regions, *viz.*, North-West India, Rajputana and the Deccan have high evaporation. Malabar, the Burma coast and North East India are also the areas where the annual rainfall is in excess of the annual evaporation, the excess being most pronounced in the coastal regions and in Assam. Evaporation is

predominating over rainfall elsewhere, and to the extent of 100" and more over the Bombay Deccan, Rajputana and Sind. The values of "rainfall minus evaporation" for individual months are given in *Table 2*, Column 8.

A comparison of the above account and the evaporation charts with the climatological maps showing the mean daily temperature, humidity, wind, cloudiness, etc.,* shows that evaporation in India closely follows the march of the seasons. The light winds, weak insolation and low temperatures of the cool season cause only slight evaporation over North India; the Bombay Deccan and the adjoining tracts with relatively greater insolation and air temperature are areas of maximum evaporation during the winter and pre-monsoon seasons. With the advent of summer conditions, higher temperatures, greater deficiency of saturation of moisture in the atmosphere, stronger air movements set in and the evaporation also increases everywhere, becoming highest in April and May. The whole central portion of the country represents the area of high evaporation at this time of the year. When the South West monsoon sets in with its strong moisture-laden winds and heavy precipitation, the west coast of India and Burma and North East India experience a sudden check in the rate of evaporation; the region of maximum evaporation which lay over the Bombay Deccan also recedes towards Sind and Rajputana. During August and September the full effect of the monsoon begins to be felt in North West India and the intensity of evaporation weakens even there. Later with the retreat of the monsoon and the setting in of the autumn in North India the evaporation "high" commences its southward movement towards the Deccan. In November and December wintry conditions are established. It is, however, only after other parts of India have experienced the vicissitudes of the South West monsoon that South East Madras begins to experience the North-East monsoon and its associated rains; the moderate and steady evaporation over this area now decreases temporarily.

Figures 2 to *11* show the mean monthly evaporation, rainfall, percentage humidity, wind velocity and temperature in different months for a few stations, selected with a view to bring out the special features of the different parts of India.

Figures 2, 3, 4 and *5* are of the continental type with extreme variations from winter to summer; Jacobabad in spite of its reputation for very high temperatures in summer has less wind movement and is therefore not able to compete with Aurangabad in evaporating power.

Figure 6, Bogra, represents the extreme humid type of North East India, *viz.*, low evaporation throughout the year, in summer due to high saturation and in winter due to low temperature.

Figures 7 and *8*, Mangalore and Rangoon, represent the South-West monsoon type, there is a high percentage of saturation all through the year and he evaporation which is already low in summer decreases still further when the South-West monsoon sets in.

Figures 9 and *10*, Madras and Pamban, represent the North-East monsoon type.

Figure 11, Karachi, is interesting; here the evaporation is moderate and uniform throughout the year. In winter, though the temperature is low and the wind is light, the air is dry and promotes evaporation; in summer the saturation is high but the high winds and higher temperature keep up the evaporation.

5. Evaporation and Salt-works.†—The subject of evaporation is of great importance to salt-works. This industry can thrive on a commercial scale only at

* Eliot's Climatological Atlas of India.

† There are also smaller areas in the interior with salt deposits, *e.g.*, Hyderabad Deccan Sambhar Lake.

places where the works will progress throughout or during a large part of the year without interruption or damage by rains The ideal conditions are :—

(1) Proximity to sea in order to have easy access to brine,

(2) scanty or no rainfall,

(3) strong insolation which, in turn, would depend upon cloudless skies

(4) moderate to high air temperature with large deficiency of moisture.

(5) moderate to strong winds, and

(6) moderate to high evaporation throughout the year, which, in turn, depends upon the first five factors.

Obviously one has to look for suitable areas along the coasts of India, an examination of the evaporation charts shows that the following areas are suited to salt-works in the order in which they are mentioned :—

(1) Mekran, Baluchistan, Sind and Kathiawar coasts, of these the Mekran and Baluchistan coasts are comparatively inaccessible to trade.

(2) The southern half of the Coromandel coast, between Negapatam and Cape Comorin.

(3) The north Madras coast between Nellore and Gopalpur.

The mean weather factors at one station in each of the above areas are given below in order to show why they should be placed in the above order. The corresponding data for Mangalore and Akyab are also given to show their extreme unsuitability.

Name of Station	Annual Rainfall	No of rainy days during year	Mean air temperature	Mean % H	Mean V P in inches of Hg	Mean wind velocity	Mean evaporation.	Mean rain minus evaporation
Karachi .	7·56	10	78	71	0·697	5·43	91·74	—84·18
Dwarka	13·52	20	78	75	0·759	6·64	98·12	—84·60
Pamban	37·00	30	82	75	0·848	5·15	88·40	—51·40
Gopalpur .	44·96	60	80	75	0·772	5·32	89·58	—44·62
Mangalore	125·68	120	79	79	0·794	1·64	46·62	+79·06
Akyab	203·37	125	79	83	0·794	1·69	35·00	+168·37

7. Evaporating power of the atmosphere in relation to plant life.– So far, by evaporation, we have meant the evaporating power of the atmosphere with respect to a free surface of water at 4 feet above ground When we consider evaporation in relation to the plant-world we have to consider three factors, *viz.*,

(1) evaporation from the soil surface,

(2) transpiration from leaves,

(3) transpiration from the stems, this is only a small proportion of the transpiration loss.

Whereas (1) is a physical process, (2) and (3) are also controlled partly by the physiological processes of the plant.

Measurements of these factors in India are very scanty. The work done at Pusa by Dr. Leather on the water-requirements of crops in India throws some light so far as transpiration is concerned. Our knowledge of evaporation from the soil under natural conditions is practically nil in India.

It may however be expected that, in areas which receive frequent rains during the monsoon and have a moist soil surface, the calculated evaporation may be expected to give a better relation to soil evaporation than during other seasons. Experiments on soil evaporation are needed before one could venture to draw any general conclusions.

In conclusion the authors desire to express their grateful thanks to Dr. L. A. Ramdas for his continued interest and guidance.

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TABLE 2.

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
1 Tavoy								
January	29 91	0 56	74	·692	·101	3 13	0 20	— 2·93
February	92	0 62	70	·664	·134	3 75	0·44	— 3 31
March	89	0 68	69	·717	·152	4 71	1 59	— 3 12
April	85	0 68	74	·816	·135	4 05	2·63	— 1 42
May	80	0 79	84	·860	·079	2 45	22 71	+20 26
June	·77	0 84	90	·874	·048	1 44	44 24	+42·80
July	77	0 79	91	855	·041	1 27	49 22	+47 95
August	·79	0 73	91	·851	040	1 24	47 33	+46 09
September	·81	0·62	91	·853	039	1 17	33 06	+31·89
October	·86	0 56	85	·851	·069	2 14	10 66	+ 8 52
November	90	0 62	79	·760	094	2 82	2 30	— 0 52
December	29 93	0·62	78	·693	091	2·82	0 36	— 2 46
Annual	..	..	..	.	..	30·99	214·71	+183·75

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
2 Rangoon								
January	29·95	1·53	69	·555	·110	4·31	0·21	− 4·10
February	·91	1·53	66	·56[illegible]	·173	4·84	0·22	− 4·62
March .	·87	1·86	68	·682	·192	5·95	0·32	5·63
April . .	·83	2·37	71	·790	·211	6·33	1·63	4·70
May	·76	1·98	83	·880	·111	3·44	11·95	+ 8·51
June .	·71	2·09	89	·912	·071	2·13	18·04	+ 15·91
July .	·71	2·09	90	·896	·062	1·92	21·42	+ 19·50
August ..	·73	1·86	91	·892	·053	1·64	19·87	+ 18·23
September	·78	1·47	90	·895	·055	1·65	15·27	+ 13·62
October	·85	1·24	86	·884	·077	2·39	6·91	+ 4·52
November ..	·91	1·53	82	·775	·096	2·88	2·79	− 0·09
December	29·95	1·75	77	·618	·114	3·53	0·57	− 3·16
Annual ..						41·04	99·03	+ 57·99
3. Akyab								
January ..	29·97	1·12	74	·504	·098	3·04	0·06	− 2·98
February ..	·93	1·76	67	·529	·153	4·28	0·15	4·13
March .. .	·88	1·89	72	·686	·161	4·99	0·49	4·50
April .. .	·82	1·96	75	·833	·169	5·07	2·07	3·00
May .. .	·73	1·89	81	·922	·131	4·06	13·95	+ 9·89
June	·63	2·03	91	·915	·059	1·77	16·94	+ 15·17
July	·62	2·10	92	·972	·052	1·61	54·80	+ 53·19
August	·66	1·84	93	·951	·043	1·33	45·19	+ 43·86
September	·73	1·55	91	·956	·054	1·62	22·57	+ 20·95
October	·84	1·28	87	·896	·072	2·23	10·91	+ 8·68
November	·91	1·22	84	·914	·095	2·85	5·48	+ 2·63
December	29·96	1·28	82	·590	·070	2·15	0·76	— 1·39
Annual		..	.	..	..	35·00	203·37	+168·37

	Pressure. (1)	Wind. (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
4. Minbu.								
January	29·84	1·97	64	·417	·148	4 59	0 04	— 4·55
February	·77	2 16	59	·418	·184	5 15	0·06	— 5·09
March	·71	2 47	51	·486	·311	9 64	0 29	— 9·35
April	64	3 09	56	·618	·357	10·71	0·77	— 9·94
May	·57	3 33	68	·767	·275	8 53	5·64	— 2·89
June	·50	3 95	82	·882	·161	4·83	5·75	+ 0·92
July	·49	4 01	82	·879	·162	5 02	4·52	— 0·50
August	·52	3 76	84	·877	135	4·19	5 27	+ 1·08
September	·60	2 78	83	·868	·125	3·75	6·20	+ 2·45
October	·70	2 04	81	814	·119	3 69	4·51	+ 0·82
November	79	2 28	76	651	·133	3 99	1·82	— 2·17
December	29 84	2 22	67	476	·150	4 65	0·51	— 4 14
Annual	..	..		.	..	68·74	35·38	+33 36
5. Yamethin.								
January .. .	29 33	1·28	67	·429	·115	3 57	0 10	— 3 47
February	27	1·28	52	·439	·220	6·16	0 22	— 5·94
March	·22	1·77	45	·500	·365	11·32	0 37	—10·95
April	·16	2·26	55	·672	·358	10·74	1 50	— 9·24
May	·10	2 75	72	784	216	6 69	5 80	— 0·89
June	·04	3·23	80	830	158	4·74	5 11	+ 0·37
July	·03	3·60	82	·818	·144	4 46	3·91	— 0·55
August	·06	3·05	85	·823	·120	3 72	5·91	+ 2·19
September	·18	2·14	85	·839	·095	2·85	7·16	+ 4·31
October	·22	1·59	83	·828	·098	3·04	5 55	+ 2·51
November	·20	1·28	82	·682	·082	2·46	1·89	— 0·57
December	29·33	1·34	80	·533	·074	2·29	0·50	— 1·79
Annual	..	..	..	..	..	62·04	38·02	—24·02

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
6. Mandalay								
January ..	29 75	0 84	72	440	084	2 60	0 05	— 2 55
February .	69	1 07	63	437	·132	3 70	0 08	— 3·62
March	62	1 57	48	468	289	8 96	0 19	— 8 77
April	53	2 36	51	601	379	11 37	1 12	—10·25
May ..	49	2 64	63	758	306	9 49	5 85	— 3·64
June . .	42	3 37	76	865	181	5 43	5 52	+ 0 09
July .. .	40	3 65	74	845	·237	7 35	3·29	— 4·06
August .. .	44	3 20	78	852	181	5 61	4·59	— 1 02
September	52	1 97	80	868	134	4 02	5 74	+ 1 72
October	62	1 35	79	816	119	3 69	4 72	+ 1 03
November	70	0 96	80	664	084	2 52	1 63	— 0 89
December	29 76	0 96	74	·497	088	2 73	0 38	— 2 35
Annual	..	..	..	..	.	67 47	33·16	—34 31
7. Bhamo.								
January	29 64	0·90	86	·369	030	0 93	0 49	— 0·44
February .. .	57	1 02	85	429	039	1·09	0 48	— 0 61
March .. .	51	1 02	77	·503	·153	4·71	0 75	— 3·99
April .. .	44	1 61	73	580	122	3 66	1 89	— 1 77
May	36	1 26	77	732	119	3 69	6·14	+ 2 45
June	28	0·96	91	·898	·045	1 35	13 88	+12 53
July	·26	0 72	92	·915	039	1·21	16 78	+15·57
August	·30	0 60	92	·904	·037	1·15	15·38	+14·23
September	·39	0·84	90	·869	·048	1 44	9·89	+ 8·45
October	·50	0·72	87	·748	054	1·67	4·26	+ 2·59
November	·60	0·54	88	·561	·035	1·05	1·50	+ 0 45
December	29·66	0·72	84	·400	·037	1·15	0·57	— 0·58
Annual	..	..	..	..	..	23·13	72·01	+48·88

	Pressure (1)	Wind (2)	Humidity (3)	Vapour pressure (4)	Mean daily evaporation (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
8. Myitkina.								
January ..	29 55	0 82	80	·352	013	1 33	0 41	− 0 92
February . .	48	1 11	81	422	052	1 46	0 85	− 0 61
March	42	1 58	74	478	097	3 01	0 94	− 2 07
April .	35	1 76	71	535	·130	3 90	1 96	− 1 94
May	27	1 29	75	689	125	3 88	6 06	+ 2 18
June .	17	1 00	90	864	049	1 47	15 13	+ 13 66
July . .	15	0 88	91	889	044	1 36	19 17	+17 81
August .	19	1 00	91	882	045	1 40	16 37	+14 97
September	28	0 85	89	852	[illegible]	1 59	9 68	+ 8 09
October	40	0 82	85	716	062	1 92	6 83	+ 4 91
November .	50	0 88	83	541	055	1 65	1·17	− 0 48
December .	29 56	0 82	79	403	053	1 64	0 42	− 1 22
Annual . .	.	.	.			24 61	78 99	+54 38
9. Sibsagar.								
January . ..	29·72	0·75	89	437	·026	0 81	1 29	+ 0 48
February	66	1·07	86	466	039	1 09	2 01	+ 0·92
March .	58	1·32	83	558	062	1 92	4 78	+ 2 86
April .	51	1 51	84	665	072	2 16	10 11	+ 7 95
May .. .	42	1·32	85	844	078	2 42	11 89	+ 9 47
June ..	30	1 26	87	932	081	2 43	14 21	+ 11 78
July ..	27	1 32	87	973	080	2 48	17 01	+ 14 53
August ..	33	1 20	87	972	077	2 39	16 27	+13 88
September ..	43	1 07	88	937	066	1 98	11 70	+ 9 72
October	57	0 82	88	805	054	1 67	5 10	+ 3 43
November . .	68	0 69	88	601	039	1 17	1 10	− 0 07
December . .	29 73	0 63	88	458	·029	0 90	0 52	− 0 38
Annual .. .	..			.	..	21 42	95 99	+ 74 57

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
10. Gauhati								
January	29 86	0 69	86	457	035	1 09	0 31	— 0 78
February	80	0 88	77	461	068	1 90	1 24	— 0 76
March	71	1 13	71	532	113	3 50	2 29	— 1 08
April	·63	1 10	76	661	110	3 30	6 61	+ 3 31
May	56	1 00	79	802	109	3 38	8 71	+ 5 33
June	42	0 81	83	918	093	2 79	13 83	+11 04
July	39	0 75	83	974	097	3 01	11 74	+ 8 73
August	45	0 69	81	965	108	3 35	10 36	+ 7 01
September	55	0 75	82	939	100	3 00	6 82	+ 3 82
October	70	0 69	81	807	090	2 79	2 79	0
November	81	0 63	84	629	056	1 68	0·44	— 1 24
December	29 86	0 63	85	492	040	1 24	0 15	— 1 09
Annual						28 74	65 29	+36 55
11. Noakhali								
January	29 97	0 82	73	472	·083	2 57	0 27	— 2·30
February	93	1 05	72	537	106	2 97	1·13	— 1·84
March	85	1 58	70	748	·115	3·57	2·65	— 0 92
April	77	2 40	79	838	·148	4·44	6 40	+ 1 96
May	68	2 22	81	907	140	4 34	11 40	+ 7·06
June	·56	2 81	87	965	097	2·91	21·49	+18·58
July	·55	2 ·92	89	·954	·083	2 57	24 35	+21·78
August	·59	2·75	90	·965	·079	2·45	26·21	+23·76
September	·69	1·75	90	·950	·065	1·95	16·63	+14·68
October	·82	0·90	84	·865	083	2 57	8·36	+ 5·79
November	·91	0·70	80	·669	·081	2·43	1·74	— 0·69
December	29·97	0·70	76	·504	·074	2·29	0·28	— 2·01
Annual	..	..	..		.	35·06	120·91	+85·85

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
12 Barisal								
January	30 00	0 62	73	·480	082	2 54	0·41	— 2·13
February	29 95	0 80	71	538	107	3 00	1 05	— 1·95
March	87	1 36	75	711	130	4 03	2 22	— 1·81
April	78	2 10	77	851	159	4 77	4 78	+ 0·01
May	69	1 85	79	930	149	4 62	9 02	+ 4·40
June	57	1 67	86	981	093	2 79	16 33	+13·54
July	55	1 67	88	980	077	2 39	15 60	+13 21
August	60	1 42	88	97[illegible]	073	2 26	13 62	+11 36
September	70	0 99	87	968	074	2 22	11 15	+ 8 93
October	84	0 68	81	874	097	3 01	6 26	+ 3 25
November	29 93	0 62	77	679	094	2 82	1 48	— 1 34
December	30 00	0 55	75	508	077	2 39	0 39	— 2 00
Annual		.				36 84	82 31	+45·47
13 Calcutta.								
January	30 01	1 13	73	446	101	3 13	0 34	— 2·79
February	29 95	1 47	70	503	104	2 91	1 10	— 1 81
March	85	2 03	68	643	187	5 80	1 44	— 4 36
April	75	2 83	72	800	218	6 57	1 89	— 4 68
May	66	2 83	76	903	201	6 23	5 75	— 0 48
June	53	2 43	81	960	122	3 66	11 90	+ 8 24
July	51	2 15	87	973	092	2 85	12 51	+ 9 66
August	56	1 98	88	968	081	2 51	12 69	+10 18
September	68	1 64	87	954	082	2 54	9 87	+ 7 33
October	83	1 19	83	845	102	3 16	4 19	+ 1 03
November	29 95	1 07	78	620	090	2 70	0 66	— 2 04
December	30 02	1 07	73	442	084	2 60	0·20	— 2 40
Annual ..	..					44 66	62·54	+17·88

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches (8)
14. Saugor Island								
January	[illegible]·01	2 97	78	[illegible]	107	3 32	0 30	− 3 02
February	[illegible]	[illegible]	74	[illegible]	[illegible]	[illegible]	1 12	3 61
March	[illegible]	[illegible]	[illegible]	74	[illegible]	9 21	1 13	− 7 78
April	77	7 [illegible]	74	[illegible]	[illegible]	10 98	1 11	− 9 81
May	[illegible]	7 14	[illegible]	[illegible]62	316	9 80	4 [illegible]	− 5 39
June	54	[illegible]	[illegible]	1 [illegible]	229	6 57	11 51	+ 4 67
July ..	52	[illegible]	[illegible]	[illegible]	181	[illegible] 61	11 [illegible]	+ 9 04
August ..	77	[illegible]	[illegible]	[illegible]	[illegible]	4 22	14 18	+ 9 96
September	[illegible]	[illegible] 71	[illegible]	[illegible]71	128	3 84	10 76	+ 6 92
October	[illegible]	3 14	[illegible]	[illegible]	133	4 12	8 14	+ 4 02
November ..	29 [illegible]	2 91	81	[illegible]	115	3 [illegible]	1 47	− 1 98
December ..	[illegible]	2 [illegible]7	[illegible]	521	100	3 10	0 27	− 2 83
Annual ..						[illegible] 25	69 41	+ 0·16
15. [illegible]								
January	[illegible]	[illegible]	61	[illegible]	103	3 19	0 36	− 2 83
February	87	0 [illegible]	[illegible]	420	113	4 00	1 25	2 75
March ..	77	1 [illegible]	56	569	215	6 67	1 67	− 5 00
April ..	66	1 [illegible]	67	7[illegible]1	214	6 12	2 11	4 31
May ..	57	1 [illegible]7	75	[illegible]	172	5 33	6 13	+ 0 80
June ..	45	1 87	83	930	115	3 45	10 24	+ 6 79
July ..	43	1 63	96	[illegible]7	090	2 79	12 57	+ 9·78
August ..	49	1 [illegible]	[illegible]	[illegible]	079	2 45	11 26	+ 8 81
September ..	60	1 14	87	936	073	2 19	8 60	+ 6 41
October ..	·76	0 72	73	801	102	3 16	3 43	+ 0 27
November ..	83	0 66	72	[illegible]2	103	3 09	0 86	− 2 23
December ..	29 91	0 66	[illegible]	396	·109	3 38	0 15	− 3 23
Annual ..	.	.			.	46 12	58 63	+12·61

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches (8)
16. Mymensingh.								
January	29·96	0·48	76	433	·062	1 92	0·33	— 1·59
February	91	0 75	72	449	084	2 35	0 94	— 1·41
March	·82	1 23	71	·576	125	3 88	2 09	— 1 79
April	74	1 92	76	723	139	4 17	5 75	— 1 58
May	66	1 71	82	826	106	3 29	12 54	+ 9 25
June	51	1 71	88	937	075	2 25	18 71	+16 46
July	52	1 64	89	966	069	2 14	16 46	+14 32
August	57	1 51	89	971	067	2 08	15 64	+13 56
September	67	1 03	89	957	·060	1 80	13 74	+11 94
October	80	0 62	84	843	075	2 33	5 80	+ 3 47
November	90	0 11	81	643	067	2 01	0 88	— 1 13
December	29 97	0 31	80	476	052	1 61	0 07	— 1 54
Annual		.		.	..	29 83	92 95	+63 12
17. Bogra.								
January	29 96	0 37	72	406	073	2 26	0 38	— 1 88
February	90	0 75	67	414	098	2 74	0 78	— 1 96
March	79	1 26	62	503	165	5 12	1 24	— 3 88
April	70	1 57	70	707	173	5 19	2 27	— 2 92
May	68	1 45	78	838	132	4 09	8 50	+ 4 41
June	51	1 26	85	938	·089	2 67	14 03	+11 36
July	·49	1 26	87	976	078	2 42	13 06	+10 64
August	54	1 07	87	970	·075	2 33	13 29	+10 96
September	65	0 94	86	954	·078	2 42	11 67	+ 9·25
October	·79	0 63	82	836	·086	2 67	4·96	+ 2 29
November	89	0 50	78	611	092	2 72	0·74	— 1 98
December	29·96	0·50	75	·439	·066	2 05	0 05	— 2·00
Annual					..	36·68	70·07	+34·29

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
18. Ranchi.								
January .. .	27 83	2 32	55	282	156	4 84	0 79	— 4 05
February	79	2 62	54	303	183	5·14	1 60	— 3 54
March .	73	2 98	40	310	331	10 26	1 30	– 8 96
April .	65	3 27	38	377	483	14 49	0 95	—13·54
May ..	56	3 21	48	533	449	13 92	2 41	—11·51
June ..	44	3 63	71	748	218	6 54	9 68	+ 3·14
July ..	·42	3 33	88	860	103	3 19	14 77	+11·58
August .. .	46	3·03	88	796	082	2 54	13 17	+10 63
September .. .	58	2 80	82	744	119	3·57	9 14	+ 5 57
October ..	72	2 02	68	570	172	5 33	2 84	— 2 49
November ..	81	1·79	60	381	157	4 71	0 38	— 4 33
December ..	27 85	1 96	53	277	156	4 84	0 18	— 4 66
Annual .						79 37	57 21	—22 16
19. Angul.								
January . ..	29 57	1 96	62	·425	·160	4 96	0 46	— 4·50
February . ..	49	2 35	61	477	200	5 60	1 40	— 4 20
March .. .	·42	2 68	53	530	326	10 11	0 99	— 9 12
April	·32	3 13	58	672	.362	10 86	1 30	— 9·56
May	·21	3·72	64	·809	370	11 47	1·98	— 9·49
June	09	3 40	75	849	·220	9 60	8 85	— 0·75
July .. .	·09	3 13	82	885	·146	4 53	10 99	+ 6·46
August	·13	3 20	84	884	·126	3 91	10 80	+ 6 89
September	·24	2 55	84	·889	·116	3 48	6·08	+ 2 60
October	39	1 96	77	·752	·138	4 28	3 66	— 0 62
November	·50	1·89	70	569	·148	4·44	1·11	— 3·33
December	29·57	1·96	66	·420	·133	4·12	0 21	— 3·91
Annual . .	.	..		.	.	77·36	47·83	—29·53

—	Pressure. (1)	Wind. (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
20. Dharbhanga.								
January . ..	29·87	0 89	77	401	059	1 83	0 46	— 1·37
February .. .	80	1 37	70	398	094	2 63	0 54	— 2 09
March .	69	1 73	56	430	198	6 14	0 50	— 5 64
April .	59	2 32	58	585	277	8 31	0 72	— 7 59
May . ..	51	2 62	64	749	179	5 55	2 78	— 2 77
June	38	2 56	78	9[illegible]8	174	5 22	8 03	+ 2·81
July	36	2 14	85	972	109	3 38	11 64	+ 8 26
August	42	1 90	86	981	097	3 01	13 96	+10 95
September ..	53	1 61	83	941	111	3 33	8 96	+ 5 63
October .	70	0 83	78	778	107	3 32	2 39	+ 0 93
November	82	0 54	77	543	074	2 22	0 21	— 2 01
December	29 88	0 71	78	380	051	1 58	0 08	— 1 50
Annual						46 52	50 27	+ 3 75
21 Patna.								
January .	29 85	1·10	67	379	097	3 01	0 53	— 2·48
February	78	1 51	59	380	140	4 17	0 71	— 3 46
March .	67	1·86	45	395	291	9 02	0·47	— 8 55
April	56	2·38	56	508	409	12 27	0·30	—11 97
May	46	2 86	72	·714	400	12 40	1 67	—10 73
June .	34	2 79	84	903	248	7 44	8·12	+ 0·68
July	32	2·32	85	982	123	3 81	11 94	+ 8 13
August .	38	2·21	80	990	112	3 47	13 55	+10 08
September	50	1·80	69	938	140	4 20	8 33	+ 4 13
October .	·67	1·05	65	734	170	5 27	2·54	— 2·73
November ..	80	0·81	66	508	134	4 02	0 28	— 3 74
December	29·86	0·87	66	·388	099	3·07	0 09	— 2 98
Annual	..	.	.	.	..	72·15	48 53	23·02

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
22. Gorakhpur.								
January . ..	29 77	0 65	73	359	·062	2 92	0 67	— 1·25
February	70	0 95	66	385	·095	2 66	0 60	— 2 06
March	59	1 31	50	388	211	6 54	0·39	— 6·15
April ..	48	1 61	17	502	327	9 81	0 40	— 9 41
May .	40	1 55	55	675	316	9 80	1·47	— 8 33
June ..	28	1·43	72	885	·195	5 85	7·41	+ 1 56
July	26	1 07	84	·968	·096	2 98	13 43	+ 10 45
August ..	31	1 01	85	963	087	2 70	13 99	+ 11 29
September ..	43	0 89	80	901	113	3 39	8 07	+ 4 68
October .	60	0 51	75	705	106	3 29	3 45	+ 0 16
November .	72	0 42	71	490	089	2 67	0 17	— 2 50
December	29 78	0 48	73	375	063	1 95	0 14	— 1 81
Annual .						53 56	50 19	— 3·37
23 Allahabad								
January ..	29 73	1 50	66	313	099	3 07	0·76	— 2·31
February .	67	1 83	58	316	·150	4·20	0·58	— 3·62
March	·56	2 22	40	·338	325	10 08	0·31	— 9·77
April	·44	2 35	32	·369	517	15·51	0·15	—15·36
May	·32	2 81	35	511	675	20 93	0·34	—20 59
June .. .	·20	3 27	58	·785	433	12 99	4·96	— 8·03
July .. .	·19	3·00	78	931	·192	5·95	11·71	+ 5·76
August	25	2 68	82	·932	113	4·43	11·70	+ 7·27
September	38	2 29	78	878	·162	4·86	5·67	+ 0·81
October	·55	1·31	59	·606	274	8·49	2·32	— 6·17
November .. .	·68	0·91	60	·428	·143	4·29	0·33	— 3·96
December	29·75	1·18	65	·344	·098	3·04	0·23	— 2·81
Annual	.			.	..	97·84	39·06	—58·78

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
24. Cawnpore.								
January ..	29·61	1·12	69	·322	·076	2·36	0·51	— 1·85
February . .	·55	1·41	63	331	·108	3·02	0·66	— 2·36
March .	·15	1·65	42	·335	·269	8·34	0·30	— 8·04
April	·33	1·71	36	403	·423	12·69	0·21	—12·48
May	21	1·82	38	·541	·530	16·43	0·40	—16·03
June	09	2·00	55	·781	·401	12·03	3·32	— 8·71
July	08	1·88	75	924	·188	5·83	10·55	+ 4·72
August	14	1·53	82	·935	·118	3·66	11·38	+ 7·72
September	27	1·35	76	838	·146	4·38	6·74	+ 2·36
October	41	0·88	63	558	·163	5·05	1·27	— 3·78
November	57	0·71	62	391	·115	3·45	0·40	— 3·05
December .	29·63	0·88	68	312·	073	2·26	0·18	— 2·08
Annual ..			.		.	79·50	35·92	—43·58
25. Bahraich.								
January .	29·61	0·92	74	345	061	1·89	0·92	— 0·97
February	54	1·22	69	·354	085	2·38	0·91	— 1·47
March	44	1·59	54	·393	·193	5·98	0·49	— 5·49
April .	32	1·95	45	·475	·352	10·56	0·32	—10·24
May	·23	1·95	50	·627	·387	12·00	1·67	—10·33
June	·12	1·95	68	·859	·250	7·50	6·02	— 1·48
July	·10	1·52	80	·915	·135	4·19	10·90	+ 6·71
August ..	15	1·22	83	·941	101	3·22	13·25	+10·03
September	27	1·10	78	·878	·130	3·90	8·72	+ 4·82
October . .	·44	0·73	70	·663	·137	4·25	1·54	— 2·71
November	·57	0·67	70	·461	·094	2·82	0·28	— 2·54
December	29·62	0·67	72	·324	·060	1·80	0·28	— 1·52
Annual	..	..	..	..	..	60·49	45·30	−15·1

—	Pressure. (1)	Wind. (2)	Humidity %. (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
26. Jhansi.								
January ..	29 21	1·15	51	·315	161	4·99	0 59	— 4 40
February	·15	1 52	45	·310	·216	6 05	0·45	— 5 60
March	·06	1·76	34	·331	384	11·90	0 29	—11 61
April .. .	28 95	2 06	30	·401	589	17 67	0 15	—17 52
May	·84	2 55	32	·493	·720	22 32	0·38	—21 94
June	·71	2 97	51	743	·525	15 75	4 30	—11 45
July	·69	2 48	74	·882	211	6 54	11·57	+ 5 03
August	·75	2 12	78	871	·158	4·90	11 25	+ 6 35
September .	68	1 82	71	796	·197	5·91	5 92	+ 0 01
October . ..	29 05	1 27	47	·509	314	9·73	0·87	— 8 86
November . ..	17	0 97	44	·367	·238	7 14	0 17	— 6 97
December ..	29 23	0 97	50	·319	·163	5 05	0 23	— 4 82
Annual .. .			.	..		117 95	36 17	--81·78
27. Agra.								
January ..	29·48	1 51	56	300	·134	4 15	0·54	— 3·61
February	·42	1 74	51	·308	·175	4 90	0·48	— 4·42
March	·32	2·09	40	337	·319	9·89	0 35	— 9·54
April	·20	2·21	32	·388	·532	15 96	0·24	—15·72
May	·08	2 56	33	·495	·688	21 33	0 47	—20·86
June	28 95	2·85	50	·733	·527	15 81	2 35	—13·46
July	·94	2·50	71	·913	254	7·87	9 12	+ 1·25
August . ..	29 00	2·15	75	·694	·147	4·56	8·15	+ 3·59
September .. .	·13	1·98	68	·800	·234	7 02	4·05	— 2·97
October .. .	·30	1·34	47	·485	·302	9·36	0·76	— 8·60
November	·43	1·10	47	·344	·203	6 09	0·12	— 5·97
December	29·50	1·22	54	·294	·134	4·15	0·27	— 3·88
Annual	..	..	..		..	111·09	26·90	—84·19

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
28. Patiala.								
January .	29 19	1 93	61	·289	·114	3 53	1 33	— 2 20
February .	12	2 28	60	·298	108	3 02	1·26	— 2 76
March	03	2 57	51	·351	·231	7·16	1 22	— 5·94
April .	28 93	2 52	43	·408	·370	11·10	0 59	—10 51
May .	81	2 75	43	540	·511	15·84	0 69	—15·15
June .	69	2 93	55	·726	435	13 05	2 52	—10 53
July	67	2 52	73	·915	·232	7 19	6·07	— 1·12
August .	·73	2 11	79	·924	·158	4 90	6·69	+ 1 79
September .	86	1 87	69	775	·213	6 39	4 54	— 1 85
October	29 03	1 52	54	·485	242	7 50	0 72	— 6·78
November	·15	1 35	52	·334	·170	5 10	0 15	— 4 95
December	29 20	1 70	61	·286	·018	3 35	0 33	— 3 02
Annual	.	..		.		88 13	26 11	—62 02
29. Ludhiana								
January	29 20	0 73	67	282	067	2 08	1 72	— 0 36
February .. .	14	0 93	63	·292	087	2 44	1 29	— 1·15
March	05	1 07	52	331	160	4 96	1 06	— 3 90
April	28 93	1·13	39	·364	301	9 03	0 85	— 8 18
May ..	81	1·20	36	451	·434	13 45	0 64	—12 81
June	69	1 33	47	621	405	12 15	2 53	— 9·62
July	·68	1 13	67	841	221	6 85	8 20	+ 1·35
August	74	0 87	75	878	·148	4 59	6 94	+ 2·35
September	·87	0 67	69	·735	159	4 79	4 24	— 0·55
October	29 04	0 47	52	412	·189	5 86	0 48	— 5·38
November	16	0 47	52	305	·130	3 90	0·11	— 3·79
December	29·22	0 53	61	269	·080	2 60	0·65	— 1·95
Annual	..	..	..	..	..	72·70	28·71	—43·99

—	Pressure. (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
30 Lahore.								
January	29 ·32	0 76	73	·268	·048	1 49	1·56	+ 0·07
February .. .	·26	1 02	69	292	068	1 90	1 35	− 0 55
March .	17	1 34	58	358	·144	4 46	2 25	— 2 21
April .	04	1 47	44	392	·283	8·49	1·85	— 6 64
May .	28 91	1 47	39	483	429	13 30	0 82	—12 48
June .	·78	1 66	44	633	437	13 11	0 36	—12 75
July ..	77	1 59	64	·845	277	8 59	1·24	— 7 35
August .. .	83	1·27	71	896	201	6 23	2 24	— 3 99
September .	97	0 96	65	733	202	6 06	0 81	— 5 25
October ..	29 14	0 70	54	447	184	5 70	0 16	— 5 54
November ..	28	0 57	63	321	088	2 64	0 28	— 2 36
December ..	29 34	0 57	69	·260	·054	1 67	0 59	— 1 08
Annual .. .	.	..		.	..	73 64	13 51	—60 13
31. Rawalpindi.								
January	28 33	0 99	63	238	073	2 26	2 49	+ 0 23
February .. .	·28	1 17	63	·250	080	2 24	2 19	— 0 05
March .	20	1 18	57	298	130	4 03	2 44	— 1 59
April	11	1·54	50	·362	212	6 36	1 94	— 4 42
May . .	27 99	1 12	38	419	393	12 18	1 34	—10 84
June .. .	86	1 36	41	512	444	13 32	2 24	—11 08
July	·83	1 17	64	·801	·216	7 63	7 66	+ 0 03
August	90	0 86	75	839	143	4 43	9 14	+ 4 71
September	28 03	0 71	64	·649	181	5 43	3 46	— 1 97
October	19	0 74	49	·364	188	5·83	0 51	— 5 32
November	31	0 68	50	·250	·122	3 66	0 26	— 3 40
December	28 35	0 74	58	·230	·082	2 54	1·10	— 1·44
Annual	..	..	..	..	..	69·91	34·77	—35·14

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches (8)
32 Multan								
January .	29 63	0 58	59	257	083	2 57	0 42	- 2 15
February .	57	0 78	56	271	103	2 88	0 36	- 2 52
March	46	0 84	50	342	169	5 24	0 43	— 4 81
April .	33	0 91	41	405	293	8 79	0 27	— 8 52
May	18	1 10	40	541	427	13 24	0 35	-12 89
June	03	1 43	44	686	492	14 76	0 62	--14 14
July	01	1 30	[illegible]	880	336	10 42	2 02	8 40
August . .	08	1 17	65	882	253	7 84	1 98	— 5 86
September .	23	1 04	60	731	253	7 59	0 41	— 7 18
October .	42	0 65	48	443	178	5 52	0 05	— 5 47
November	57	0 52	50	317	145	4 35	0 07	— 4 28
December	29 65	0 52	56	262	094	2 91	0 22	— 2 69
Annual			.			86 11	7·20	—78 91
33 Dera Ismail Khan								
January .	29 48	0 57	60	225	070	2 17	0 49	— 1 68
February	42	0 83	60	256	084	2 35	0 65	— 1 70
March .	32	0 96	58	352	130	4 03	1 02	— 3 01
April	20	1 15	50	446	237	7 11	0 74	— 6 37
May .	·05	1 21	45	574	378	11 72	0 40	—11 32
June .. .	28·89	1 21	47	714	435	13 05	0 67	—12·38
July	87	1 21	64	884	·269	8 34	2 18	— 6 16
August ..	94	0 96	71	924	193	5 98	1 94	— 4·04
September	29·09	0 76	64	723	199	5 97	0 55	— 5·42
October	·27	0 51	52	·421	179	5 55	0 09	— 5·46
November	42	0 32	56	292	101	3 03	0·16	— 2 87
December .. .	·49	0·32	59	230	070	2 17	0·20	— 1·97
Annual .. .	.	..	..	.	.	71·47	9·09	—62·38

—	Pressure. (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall – Evaporation in inches. (8)
34. Quetta.								
January	24 66	1 26	70	161	041	1·27	1·93	+ 0 66
February	63	1 51	65	167	056	1·57	1·86	+ 0 29
March	·62	1·76	56	194	099	3·07	1·88	— 1·19
April	60	1 51	47	220	·161	4 83	1·03	— 3 80
May .. .	56	1 38	13	298	239	7·41	0 37	— 7·04
June	45	1 26	40	344	307	9 21	0·15	— 9 06
July	·39	1 32	51	479	277	8·59	0·63	— 7 96
August .. .	·44	1 13	54	472	233	7·22	0 46	— 6 76
September	57	0 88	44	278	·194	5·82	0 07	— 5 75
October .. .	69	0 75	40	164	·131	4 06	0·13	— 3 93
November ..	73	0 82	49	155	·087	2 61	0·32	— 2·29
December ..	24 71	1 01	64	163	051	1·58	0 92	— 0·66
Annual .. .	.		.			57 24	9·75	—47 49
35. Jacobabad.								
January .. .	29 88	0 89	54	241	102	3 16	0 26	— 2 90
February	81	1 24	46	252	·159	4·45	0 32	— 4 13
March	70	1 60	38	307	287	8 90	0·24	— 8 66
April .. .	57	1 78	36	416	·441	13 23	0·20	— 13·93
May	42	1 89	41	629	·552	17·11	0·14	—16·97
June .. .	27	2 25	51	·804	431	12 93	0·20	—12·73
July .. .	24	2 37	61	899	·381	11 81	0·89	—10·92
August	·32	1·84	67	908	·271	8·40	0·98	— 7·42
September	47	1·36	65	779	·231	6 93	0·21	— 6·72
October .. .	66	0·95	47	·461	·263	8·15	0·04	— 8·11
November	·81	0·71	47	·319	·172	5·16	0·07	— 5·09
December	29·90	0·71	51	·248	·113	3·50	0·13	— 3·37
Annual	..	..	..	..	..	103·73	3·68	—100·05

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
36 Hyderabad (Sind)								
January	29 97	2 99	52	285	190	5·89	0·20	— 5 69
February	·91	2 86	52	·316	206	5 77	0·27	— 5·50
March .. .	80	3 44	45	390	357	11·07	0·24	—10·83
April	68	4 48	43	474	512	15 36	0·05	—15·31
May	55	5 97	50	658	691	21 42	0·20	—21 22
June	40	7 33	58	782	694	20 22	0 45	—19 77
July .. .	·36	7 20	64	826	553	17 14	2 85	—14 29
August . ..	44	6 88	68	789	428	13 27	2 12	—11 15
September	59	5 58	65	727	305	11 85	0 60	—11·25
October	·76	3 44	55	514	343	10 63	0 02	—10 61
November .. .	90	2 53	51	398	257	7 71	0 06	— 7·65
December	29·98	2 92	51	301	206	6·39	0 06	— 6 33
Annual						146 72	7 12	—139 60
37 Karachi.								
January . ..	30 06	3 78	55	372	244	7 56	0 52	— 7 04
February	30 00	4 15	59	·414	260	7 28	0 39	— 6 89
March ..	29 91	6 00	65	566	·285	8·84	0 33	— 8·51
April .. .	·80	5 92	77	756	235	7 05	0 17	— 6 94
May .. .	69	7 14	82	927	·237	7 35	0 07	— 7·28
June .. .	·53	7 63	81	979	283	8 49	0 86	— 7·63
July .. .	50	7 63	82	952	256	7 94	2 94	— 5·00
August	·57	7 20	84	·878	·197	6 11	1 67	— 4·44
September	·72	6 16	81	·838	·211	6 33	0 42	— 3·91
October	·87	4·03	68	·706	·277	8·59	0·01	— 8·58
November	29·99	3·23	60	·536	266	7·98	0·04	— 7·94
December	30·06	3·54	53	·384	·265	8·22	0·14	— 8·08
Annual	..	..	..	..	..	91·74	7·56	—84·18

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches (8)
38 Bikaner								
January	29 26	1 66	43	230	179	5 55	0 34	— 5·21
February	19	1 94	40	239	221	6 19	0 28	— 5 91
March	29 10	2 28	35	291	355	11 01	0 26	10 75
April	28 98	2 63	33	390	550	16 50	0 22	16 28
May	86	3 48	40	573	682	21 14	0 72	20 42
June	73	4 11	49	733	656	19 68	1 45	18 23
July	71	3 77	60	824	453	14 04	3 10	10 94
August	78	3 43	65	817	346	10 73	3 47	7 26
September	92	2 97	60	727	355	10 65	1 17	- 9 48
October	29·03	2 06	40	438	415	12 87	0 26	12 61
November	21	1 37	38	290	262	7 86	0 04	7 82
December	29 27	1 43	40	230	194	6 01	0 18	— 5 83
Annual						112 23	11 79	130 44
39 Jodhpur								
January .. .	29 24	1 89	35	205	234	7 25	0 14	7 11
February .	19	1 52	32	199	256	7 17	0 20	- 6 97
March	10	1 89	26	216	378	11 72	0 09	-11 63
April .. .	00	2 20	27	285	499	14 97	0 15	14 82
May ..	28 88	3 21	36	456	616	19 10	0 45	--18 65
June ..	77	3 77	52	679	510	15 30	1 45	-13 85
July ..	74	3 46	65	·792	336	10 42	3 69	- 6 73
August .	81	2 96	62	793	357	11 07	4 40	- 6 67
September ..	94	2 01	65	·693	·234	7 02	2 46	— 4 56
October .. .	29·09	1 25	37	358	330	10 23	0 36	— 9 87
November ..	·20	1 19	30	223	·279	8·37	0·11	— 8·26
December .. .	29·25	1·57	34	192	215	6·67	0·12	— 6·55
Annual	.	..	..	.	..	129·29	13·62	—115·67

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
40. Jaipur								
January	28 58	1 13	49	252	150	4 65	0 47	-- 4 18
February	53	1 72	44	248	189	5 29	0 29	- 5 00
March	45	1 95	36	277	310	9 61	0 37	- 9 24
April	35	2 25	29	320	518	15 54	0·17	-15 37
May	25	2 72	32	424	614	19 06	0 58	- 19 38
June	13	3 02	48	663	537	16 11	2 30	- 13 81
July	11	2 49	70	815	241	7 47	8 02	+ 0 55
August	17	2 19	75	820	180	5 58	7 93	+ 2 35
September	29	1 89	66	700	251	7 53	3 41	- 4 12
October	45	1 36	43	407	304	9 42	0 32	– 9 10
November	55	1 18	43	292	208	6 24	0 14	— 6 10
December	28 60	1 24	48	254	150	4 65	0 21	- 4 44
Annual						112 05	24 21	87 84
41 Deesa								
January	29 55	3 32	37	230	296	9 18	0 11	-- 9 07
February	50	3 38	36	244	334	9 35	0 16	- 9 19
March	43	3 32	31	286	483	14 97	0 08	—14 89
April	34	3 60	31	370	651	19 53	0 03	--19 50
May	26	5 26	44	592	734	22 75	0 43	—22 32
June	13	6 54	57	750	633	18 99	2 18	—16 81
July . .	09	5 93	73	851	330	10 23	9 00	— 1 23
August . .	16	4 76	78	831	216	6 70	8 62	+ 1 92
September . .	28	3 17	70	765	·246	7·38	3 54	— 3 84
October .	42	2 55	51	504	329	10 20	0 41	— 9 79
November . .	51	2 83	38	315	365	10 95	0 10	—10 85
December . ..	29·55	3 10	39	·251	·288	3 93	0·04	— 8 89
Annual .. .	..	.	..	..	.	149·16	24·70	—124 46

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
42. Bhuj								
January	29 69	2 81	51	346	·234	7 25	0 08	— 7 17
February	65	3 13	55	399	241	6 75	0 15	- 6 60
March	57	3 81	54	482	334	10 35	0 12	-10 23
April	48	5 00	53	588	492	14 76	0 07	14 69
May	39	7 31	62	776	566	17 32	0 07	17 25
June	24	7 69	68	867	505	14 76	1 79	—12 97
July	21	7 81	76	881	348	10 79	6 43	- 4 36
August	28	6 88	80	844	242	7 50	3 24	- 4 26
September .	41	5 06	74	793	216	7 98	1 88	- 6 10
October .	54	2 94	63	626	305	9 46	0 44	— 9 02
November	64	2 25	53	489	279	8 37	0 08	— 8 29
December	29 69	2 44	51	367	235	7 29	0 04	— 7 25
Annual						122 58	14 39	-108 19
43. Dwarka								
January ..	30 00	5 62	64	481	270	8 37	0 08	— 8 29
February . .	29 97	5 96	65	529	296	8 29	0 32	— 7 97
March ..	90	6 37	69	653	316	9 80	0 20	— 9 60
April . .	81	6 37	79	811	233	6 99	0 05	6 94
May ..	72	7 60	83	956	239	7 31	0 01	— 7 30
June . .	56	8 97	82	966	290	8 70	2 14	— 6 56
July .	53	9 86	82	940	302	9 36	6 03	— 3 33
August .	61	8 70	84	887	229	7 10	3 20	— 3 90
September	73	5 62	82	872	191	5 73	1 06	— 4·67
October	85	4 59	74	818	·256	7 94	0 36	— 7 58
November	29 94	5 00	67	·682	·314	9 42	0 03	— 9 39
December ..	30 00	5 00	62	·515	·295	9 11	0·04	— 9·07
Annual	..	..	..	..	..	98·12	13 52	—84·60

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches (8)
46 Neemuch								
January	28 37	2 50	46	251	205	6 36	0 21	— 6·15
February	33	2 79	42	254	253	7 08	0 20	– 6·88
March	27	3 08	30	264	462	14 32	0 08	—14 24
April	18	3 51	23	300	810	24 30	0 12	—24 18
May .	09	4 94	36	506	865	26 82	0 67	—26 15
June	27 98	5 58	57	·693	543	16 29	4 42	—11 87
July	95	5 17	76	785	246	7 63	8 89	+ 1·26
August	28 01	4 71	80	770	181	5 61	8 83	+ 3 22
September	12	3 60	73	712	214	6 42	4 85	– 1 57
October	26	2 38	50	450	305	9 46	0 54	– 8 92
November .	36	2 09	45	309	243	7 29	0 21	– 7 08
December .	28 39	2 15	47	264	194	6 01	0 17	— 5 84
Annual						137 59	29·19	—108·40
47. Sutna.								
January .. .	28 96	1 12	59	326	127	3·94	0 88	— 3 06
February ..	91	1 73	51	312	179	5 01	0 73	– 4 28
March	82	1 97	36	305	339	10·51	0 48	—10 03
April .. .	·71	2 41	28	329	·569	17 07	0·20	—16 87
May	·60	2 96	27	·416	·828	25·67	0 48	–25·19
June	48	3·70	53	·697	·507	15·21	5 92	— 9·29
July	·47	3·52	80	·870	·174	5·39	13·69	+ 8·30
August	·52	2 90	84	·871	·121	3·75	12·78	+ 9·03
September	·64	2·16	79	·829	·143	4·29	6·81	+ 2·52
October	·81	1·36	62	·575	·196	6·08	2·10	— 3·98
November	·93	1·11	57	·382	·152	4·56	0·34	— 4·22
December	28·98	1·11	58	·305	·117	3·63	0·36	— 3·27
Annual	..	..	.	..	..	105·11	44·77	—60·34

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
48. Amraoti								
January	28 77	2 08	41	318	292	9 05	0 43	— 8 62
February .	72	2 34	40	327	326	9 13	0 38	— 8 75
March ..	66	2 47	31	326	495	15 35	0 31	—15 04
April .	57	2 73	31	374	591	17·73	0 22	—17 51
May ..	49	3 50	36	495	703	21 79	0 68	—21 11
June	40	4 48	65	736	359	10 77	6 52	4 25
July	39	4 54	83	·793	148	1 59	8 76	+ 4·17
August	41	4 80	84	767	123	3 81	6 58	+ 2 77
September	52	2 53	79	718	137	4 11	6 21	+ 2 10
October	65	1 82	54	517	269	8 37	1 92	— 6 45
November	74	1 88	45	383	288	8 64	0 55	— 8 09
December	28 79	1 95	43	326	·270	8 37	0 49	— 7 88
Annual . .						121 71	33·05	—88 66
49. Khandwa								
January ..	28 95	1 45	49	294	173	5 36	0 32	— 5·04
February .. .	90	1·94	36	271	300	8 40	0·12	— 8 28
March .	84	2 36	27	·277	·392	12·15	0 14	—12 01
April	75	3 03	27	·335	520	15 60	0 10	—15·50
May	·68	4 67	38	·508	·765	23·72	0 42	—23·30
June .. .	57	4·73	63	·730	·399	11·97	5·42	— 6·55
July . ..	55	4·24	78	·797	·199	6 17	8·61	+ 2·44
August .. .	61	3 94	82	771	142	4·40	6·49	+ 2·09
September	·70	2 91	78	·748	·208	6·24	5·97	— 0·27
October ..	83	1·45	57	·521	·223	6 91	1·23	— 5·68
November	·92	1·27	49	·365	·208	6·24	0·53	— 5·71
December ..	28·96	1·21	48	·312	·182	5·64	0·28	— 5·36
Annual .. .	..	..	..	..	.	112·80	29·63	—83·17

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches. (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
50. Seoni								
January . .	27 95	1 30	51	328	177	5 49	0 58	— 4 91
February	91	1 55	48	335	213	5 96	0 94	— 5 02
March	85	1 74	35	316	360	11 16	0 67	—10·49
April	77	1 99	32	365	496	14 88	0 46	—14 42
May	68	2 30	29	405	668	20·71	0 79	—19·92
June	57	2 73	61	673	311	9 33	9 31	— 0·02
July .	56	2 79	83	780	117	3 63	15 23	+11·60
August	60	2 30	85	762	091	2 82	13 19	+10 37
September .	60	1 80	78	728	127	3 81	9 04	+ 5 23
October	84	1 30	57	510	213	6·60	1 89	— 4·71
November	93	1 18	52	377	190	5 70	0·59	— 5 11
December	27 97	1 12	52	323	161	4 99	0 53	— 4·46
Annual .. .			..			95 08	53 22	—41·86
51. Nagpur								
January .	28 98	1 45	50	345	195	6·05	0 42	—5·63
February ..	·92	1 80	46	351	248	6 94	0·60	—6·34
March ..	85	2 03	34	335	·415	12 87	0 52	—12·35
April .	76	2 44	33	395	541	16·23	0·56	—15·67
May . ..	66	3 20	30	439	777	24 09	0 83	—23 26
June ..	57	3 60	61	722	373	11 19	8·96	— 2 23
July .. .	56	3 49	82	818	142	4 40	13·84	+ 9·44
August . .	60	2 96	81	793	137	4 25	11·64	+ 7·39
September	70	2 15	77	770	146	4 38	8·25	+ 3·87
October . ..	84	1 57	60	556	·215	6·67	2·10	— 4·57
November	·94	1·51	54	·409	199	5·97	0·71	— 5·26
December	28 99	1·28	52	340	·172	5·33	0·54	— 4·79
Annual	..	..	..	..	..	108·37	48·97	—59·40

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
54 Chanda								
January	29 37	1 11	59	409	149	4 62	0 25	− 4·37
February	31	1 39	54	427	202	5 66	0 77	− 4·89
March	24	1 60	40	415	361	11·19	0·90	−10·29
April	15	1 94	40	497	459	13 77	0 66	−13 11
May	06	2 64	35	515	664	20 58	0 71	−19 87
June	28 97	3 47	60	735	386	11 58	7 66	− 3 92
July	97	3 33	79	821	168	5 21	16 10	+10·89
August	29 02	3 05	80	811	150	4 65	13 02	+ 8 37
September	09	2 08	80	815	129	3 87	9 18	+ 5 31
October	23	1 11	70	661	149	4 62	1 73	− 2·89
November	33	0 90	68	501	118	3 54	0 68	− 2 86
December	29 38	0 83	65	405	108	3 35	0 24	− 3 11
Annual						92 64	15·90	−40·74
55 Bombay								
January	29 94	5 03	70	593	237	7 35	0 10	− 7 25
February	92	5 37	68	593	271	7 59	0 08	− 7 51
March	87	5 53	72	707	272	8 43	0 07	− 8 36
April	81	5 42	74	817	282	8 46	0 05	− 8 41
May	76	5 09	76	·903	270	8 26	0 84	− 7 42
June	64	7 43	83	·933	·229	6 87	18 31	+11·44
July	·63	9 34	86	·917	·211	6 54	24 26	+17 72
August	69	7 77	86	·883	·178	5 52	13 80	+ 8·28
September	77	5·37	87	·892	·129	3 87	10 50	+ 6 63
October	83	4 58	81	854	·178	5·52	2·16	− 3·36
November	90	4 81	74	·721	·232	6 96	0 41	− 6·55
December	29 94	4·92	71	·526	·237	7·35	0·05	- 7·30
Annual						82·72	70·63	−12·09

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
56 Marmagoa.								
January	29·90	3·79	82	677	120	3·72	0·02	-3·70
February	87	4·18	83	715	124	3·47	0·07	3·40
March	83	4·31	79	803	185	5·74	0·02	5·72
April	78	4·24	75	867	247	7·41	0·75	6·66
May	75	4·90	77	910	252	7·71	2·63	5·08
June	67	7·03	88	941	120	3·60	29·59	+25·99
July	68	7·88	90	920	106	3·29	31·23	+27·94
August	73	5·03	91	908	084	2·60	15·86	+13·26
September	77	3·33	93	908	052	1·56	9·47	+7·91
October	81	2·87	92	898	055	1·71	3·78	+2·07
November	85	3·27	83	745	115	3·45	1·30	2·15
December	29·89	3·66	79	755	159	4·93	0·23	—4·70
Annual						49·19	94·95	+45·76
57. Ahmednagar								
January	27·83	2·48	37	290	342	10·60	0·26	-10·34
February	79	3·03	34	274	402	11·26	0·17	-11·09
March	75	3·64	34	358	573	17·76	0·16	—17·60
April	69	4·12	35	435	713	21·39	0·31	—21·08
May	64	7·33	50	566	576	17·63	0·91	-16·72
June	54	9·76	72	688	286	8·58	4·82	—3·76
July	53	6·73	79	690	215	6·67	3·78	—2·89
August	58	6·12	78	662	207	6·42	2·49	—3·93
September	65	4·30	76	653	186	5·58	6·36	+0·78
October	74	3·15	57	514	299	6·17	2·03	-4·14
November	80	2·67	46	385	318	9·54	0·63	—8·91
December	27·84	2·24	15	320	260	8·06	0·11	—7·65
Annual						129·66	22·33	—107·33

	Pressure. (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
58. Poona								
January	28 13	2 43	43	301	274	8 49	0 06	- 8 43
February	10	2 70	41	288	297	8 32	0 06	— 8 26
March	05	3 29	39	337	410	12 71	0 06	—12 65
April	00	4 10	37	399	591	17 73	0 57	—17 16
May	27 95	5 72	56	564	465	14 23	1 20	—13 03
June	85	6 05	72	691	294	8 82	4 77	— 4 05
July	83	6 26	82	706	174	5 39	7 01	+ 1 62
August	88	5 51	83	683	144	4 46	3 66	— 0 80
September	95	4 27	80	671	150	4 50	4 84	+ 0 34
October	28 04	2 59	69	579	183	5·67	3 74	— 1 93
November	10	2 43	54	415	245	7 35	0 98	— 6 37
December	28 14	2 32	50	327	·220	6 82	0 16	— 6 66
Annual	.	.		.	.	104·49	27 11	—77 38
59 Sholapur								
January	28 38	3 82	32	290	518	16 06	0 15	—15 91
February	34	3 67	26	260	606	16 97	0 06	—16 91
March	29	3 86	24	287	779	24 15	0 19	— 23 96
April	22	4 30	29	381	831	24 93	0 44	—24·49
May	·18	5 51	44	525	684	20 93	1 03	—19 90
June	·10	6 65	65	·666	410	12 30	4 68	— 7·62
July	·09	6 84	73	686	298	9 24	4 32	— 4 92
August	14	6 14	73	·671	272	8·43	4 87	— 3 56
September	·19	4·18	73	·670	·218	6 54	7 98	+ 1·44
October	·27	3·86	56	·538	323	10 01	3 23	— 6·78
November	·35	3 99	45	·404	·420	12 60	1 05	—11·55
December	28·39	3·80	40	·328	·409	12·68	0·45	—12·23
Annual			..	.	.	174·84	28·45	—146·39

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
60. Belgaum.								
January .. .	27·41	3 99	51	·368	308	9 55	0·13	— 9·42
February	·38	3 69	50	394	330	9 24	0·05	— 9·19
March . .	34	4 28	45	459	505	15 66	0 27	— 15·39
April ..	·30	5 00	59	570	390	11 70	1 60	- 10·10
May . .	27	6 49	72	684	307	9·39	2·46	— 6·93
June .	·19	8 75	85	683	193	5 79	8·14	+ 2 35
July .	18	10 11	92	673	092	2 85	16 15	+ 13·30
August	22	8 21	92	663	079	2 45	9 67	+ 7·22
September . ..	27	5 95	89	654	089	2 67	4 88	+ 2·21
October ..	·32	3·81	76	612	165	5 12	4 67	— 0 45
November .	·37	4 11	60	400	271	8 13	1·74	— 6·39
December ..	27 41	4 58	54	379	303	9 39	0·37	— 9·02
Annual			.	.		91 94	50 13	— 41·81
61. Aurangabad.								
January	28 09	2 71	30	2 85	·476	14 76	0 33	— 14·43
February .. .	·05	3·15	26	2 52	549	15 37	0 17	— 15·20
March	00	3 64	24	2 84	·738	22 88	0 24	— 22 64
April .. .	27 94	4 44	24	3·36	·971	29 13	0 24	— 28·89
May .. .	·88	5 74	43	5·05	707	21 92	0 85	— 21 07
June .. .	·79	6·73	69	6 89	·361	10 83	5·43	— 5 40
July	·77	6·48	81	7·16	·191	5 92	6·48	+ 0 56
August	82	6·05	82	6 90	·166	5·15	4·83	— 0·32
September	·89	4·13	75	6·66	·194	5·82	6·53	+ 0·71
October	·99	2·90	51	4·95	·351	10·88	1·56	— 9·32
November	28·07	2·71	40	3·70	·400	12·00	0·58	— 11·42
December	28·11	2·53	38	3·12	·352	10·91	0·29	— 10·62
Annual	..	..	.	..	..	165·57	27·53	—138·04

——	Pressure (1)	Wind (2)	Humidity (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
62. Gulbarga.								
January	28·47	2·75	43	341	·324	10·04	0·20	— 9·84
February	43	3·11	39	363	428	11·98	0·19	—11·79
March	37	3·36	34	390	593	18·38	0·37	—18·01
April	30	3·78	38	505	687	20·61	0·92	—19·69
May	25	5·00	48	·614	645	20·00	1·19	—18·81
June	18	6·04	65	694	404	12·12	4·69	— 7·43
July	18	6·10	76	704	243	7·53	6·18	— 1·35
August	22	5·19	75	700	·239	7·41	5·69	— 1·72
September	27	4·09	74	701	213	6·39	7·48	+ 1·09
October	36	3·29	61	591	294	9·11	3·01	— 6·10
November	43	3·42	55	483	312	9·36	1·00	— 8·36
December	28·48	2·81	50	379	273	8·46	0·16	— 8·30
Annual	..	..	.	..	..	141·39	31·08	—110·31
63. Raichur.								
January	28·66	3·21	49	·425	·337	10·45	0.10	—10·35
February	61	3·09	43	·425	·425	11·90	0·23	—10·67
March ..	·55	3·15	37	433	559	17·33	0·24	—17·09
April .	49	3·57	42	563	·625	18·75	0·70	—18·05
May .	·44	4·88	49	637	626	19·41	1·04	—18·37
June .. .	·38	6·19	64	·703	·435	13·05	3·56	— 9·49
July	38	6·43	72	·702	·306	9·49	5·08	— 4·41
August . .	·42	5·83	71	701	299	9·27	5·32	— 3·95
September .. .	47	4·28	72	·713	·245	7·35	7·19	— 0·16
October . .	·54	3·33	62	·633	·302	9·36	3·44	— 5·92
November	·61	3·09	58	·538	·292	8·76	0·95	— 7·81
December	28·66	3·03	55	·458	·278	8·62	0·15	— 8·47
Annual	..	..	..	..	..	143·74	28·00	—115·74

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
64. Hyderabad (Deccan).								
January	28 26	1 33	58	410	166	5 15	0 24	— 4 91
February	21	1 56	54	438	219	6 13	0 30	— 5 83
March	16	1 50	45	·449	318	9 86	0 72	— 9·14
April	10	1 73	44	545	420	12 60	1 05	—11 55
May	03	2 49	44	585	603	18 69	1·00	—17·69
June .	27 95	3 76	65	690	310	9 30	4 59	— 4·71
July ..	95	3 87	75	·690	195	6 05	6·49	+ 0·44
August	99	3·41	75	·703	186	5 77	6 30	+ 0·53
September ..	28·05	2 20	76	723	151	4 53	7 04	+ 2 51
October	14	1 50	67	622	178	5 52	3 25	— 2·27
November	22	1 39	64	508	163	4 89	1 10	— 3·79
December . .	28 27	1 21	62	425	·142	4 40	0·19	— 4·21
Annual . ..		.			.	92 89	32·27	—60·62
65 Hanamkonda.								
January .	29 11	2 15	57	475	229	7·10	0 32	— 6·78
February .	06	2 54	58	511	289	·8 09	0 35	— 7·74
March	00	3 07	55	560	340	10 54	0·39	—10·15
April	28·92	3 62	56	·650	411	12·33	0·93	—11·40
May	83	3·74	44	·592	·616	19 10	0·92	—18·18
June	·75	4·47	56	·682	·485	14 55	5·96	— 8·59
July . ..	75	4·17	71	·638	·226	7 01	8·99	+ 1·98
August	80	3·86	71	·742	·252	7·81	6·55	— 1·26
September	·86	2·70	72	·766	·211	6·33	6·83	+ 0·50
October . ..	·97	1·90	64	·655	·227	7 04	2·02	— 5·02
November . ..	29·06	1·78	58	·524	·228	6 84	0·94	— 5·90
December	29 12	1·59	55	·450	·213	6·60	0·22	— 6·38
Annual	..	..	..	..	..	113·34	34·42	—78·92

	Pressure. (1)	Wind (2)	Humidity % (3)	Vapour Pressure. (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
66. Chitaldrug.								
January	27 56	303	47	399	·342	10·60	0 27	—10·33
February	53	257	42	398	·389	10 89	0 09	—10 80
March .	50	·263	39	·413	·463	14 35	0 25	—14·10
April ..	·45	·283	52	·547	·373	11·19	0·92	—10 27
May	·41	395	64	·628	·306	9 49	3·05	— 6·44
June	35	·494	73	652	·235	7 05	2 84	— 4 21
July .	·35	513	79	·646	·171	5 30	3 11	— 2 19
August . ..	·38	480	78	·646	·176	5 45	2·95	— 2 50
September . ..	43	·382	77	644	·164	4 92	4·47	— 0 45
October	·47	·243	70	·604	·180	5 58	4 33	— 1 25
November ..	52	·257	63	·535	·228	6 69	2 28	— 4 41
December . ..	27 55	·309	57	·451	·261	8 09	0 34	— 7·75
Annual . ..	..	.	..	..	.	99·60	24·90	—74·70
67. Bangalore.								
January	26·97	2 68	64	·424	·174	5·39	0·26	— 5·13
February . ..	·95	2 51	60	·445	·211	5·91	0·17	— 5·74
March	92	2 40	53	463	·286	8·87	0 50	— 8·37
April	·87	2 28	61	·579	·253	7·59	1·33	— 6·26
May	·84	2 91	67	·625	·233	7 22	4·36	— 2·86
June	·78	4·28	76	·622	·180	5·40	2·89	— 2·51
July	·78	4·28	80	·609	·139	4·31	4·18	— 0·13
August	·81	3·77	80	·618	·132	4·09	5·38	+ 1·29
September	·84	3·03	80	·629	·121	3 63	6·98	+ 3·35
October	·88	2·17	76	·595	·126	3·91	5·90	+ 1·99
November	·92	2·34	72	·533	·143	4·29	2·94	— 1·35
December	26·96	2·57	69	·465	·149	4·62	0·48	— 4·14
Annual	..	..	..	..	..	65·23	35·37	—29·86

..	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
68 Hassan								
January	26 85	1 59	65	·450	·229	4 50	0·07	— 4 43
February	83	1 59	69	521	289	3 98	0·17	— 3·81
March	80	1 72	65	607	340	6 29	0 33	— 5 96
April	76	2 08	72	673	411	5 19	2 01	— 3·18
May	73	2 70	78	704	616	6 42	4 69	— 1·73
June	67	3 56	83	638	185	3 27	4 01	+ 0·74
July	67	3 19	86	619	226	2 60	5 40	+ 2 80
August	70	3 13	85	615	252	2 61	3 66	+ 1 02
September	73	2 51	83	608	211	2 61	4 27	+ 1 66
October	77	1 72	79	613	227	3 16	6 67	+ 3 51
November	80	1 73	73	·539	228	3 57	3 38	— 0·19
December	26 84	1 59	71	470	213	3 60	0 67	— 2 93
Annual						47 83	35 33	—12 50
69 Mangalore								
January	29 89	1 70	66	631	189	5 86	0 06	— 5·80
February	85	1 70	73	727	·157	4 40	0 06	— 4 34
March	82	1 70	72	·789	·179	5 30	0 08	— 5 22
April	77	1 75	70	821	207	6 21	1 28	— 5 93
May	74	1 98	74	850	·184	5 70	6 20	+ 0 50
June	71	1 98	88	872	·073	2 19	36 78	+34 59
July	72	1 86	89	858	·063	1 95	37 11	+35 16
August	75	1 47	89	·852	059	1 83	22 54	20 71
September	78	36	88	851	063	1 95	10 12	+ 8 47
October	·79	41	85	·849	082	2 54	7 53	+ 4 99
November	82	1 41	79	·781	·115	3 45	3 12	— 0 33
December	29 85	1·64	69	·653	·160	5 24	0 50	— 4 74
Annual	..	..	..	..	..	46 62	125 68	+79·06

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches. (8)
70. Cochin.								
January	29 92	2 28	72	680	171	5 30	0 69	— 4·61
February	·91	2 68	75	757	173	4 84	0 79	— 4·05
March	88	3 08	76	848	196	6 08	2 00	— 4 08
April	83	2 91	76	885	199	5 97	4 71	— 1·26
May	81	2 91	81	896	151	4 68	11·67	+ 6 99
June	80	2 74	87	861	090	2 70	28·49	+25·79
July	·82	2 80	87	836	087	2 70	22 84	+20·14
August	84	2 68	86	·838	094	2 91	12 89	+ 9 98
September	85	2 46	86	847	091	2 82	8 98	+ 6·16
October	86	2 11	85	854	·094	2 91	13 22	+10·31
November	88	1 88	83	811	100	3 00	6 54	+ 3 54
December	29 90	2 00	76	719	·139	4 31	1 74	— 2 57
Annual						48 22	114·56	+66 34
71. Trivandrum.								
January	29 71	68	77	716	125	3 88	0 74	— 3 14
February	·71	1 98	77	744	137	3 84	0 61	— 3 23
March	·68	2 22	77	805	154	4 77	1 62	— 3·15
April	·63	2 46	79	861	·152	4 56	4 47	— 0·09
May	·61	2 94	82	872	137	4 25	8 45	+ 4·20
June	·61	3·05	88	843	083	2 49	13 39	+10 90
July	·62	3 65	87	813	097	3 01	7·41	+ 4 40
August	·64	3·83	86	808	·107	3 32	4 07	+ 0 75
September	·65	3·29	84	·810	·117	3 51	4 14	+ 0 63
October	·67	2·04	87	·826	·077	2 39	10 58	+ 8 19
November	·68	1·56	87	·813	·069	2 07	6·59	+ 4 52
December	29·70	1·56	82	·750	·094	2 91	2·44	— 0·47
Annual	..	..	..	..	..	41 00	64·51	+23·51

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
72. Pamban.								
January .. .	29 91	5·68	80	780	197	6 11	2 13	— 3 98
February	·89	4·04	73	750	232	6 50	0 73	— 5 77
March	85	3 33	71	800	250	7 75	0 53	— 7 22
April	79	3 52	74	884	241	7 23	1 62	— 5 61
May ..	73	6 00	78	959	283	8 77	0 83	— 7 94
June ..	71	7 18	76	909	337	10 11	0 13	— 9 98
July	72	5 68	74	872	310	9 61	0 57	— 9 04
August	74	4 63	75	880	267	8 28	0 73	— 7 55
September .	77	4 76	76	876	253	7 59	1 20	— 6 39
October .	81	4 37	80	875	191	5·92	9 04	+ 3 12
November . ..	84	5 35	83	849	170	5 10	12 00	+ 6 90
December	29 89	6 92	84	805	175	5 43	7 49	+ 2 06
Annual ..					.	88 40	37 00	—51 40
73. Madura								
January	29 52	2 52	69	652	·198	6·14	0 60	— 5·54
February	49	2 16	65	662	·227	6 36	0 36	— 6 00
March . .	45	1 87	61	711	·275	8 53	0 51	—·8 02
April	38	1 64	62	801	·286	8 58	2 03	— 6 55
May .	32	2 57	60	787	360	11 16	2 89	— 8 27
June .. .	29	2 57	56	·728	·392	11 76	1 37	—10 39
July .	·30	2 46	57	709	359	11 12	1 92	— 9 20
August	·33	1 93	60	·727	298	9 24	4 25	— 4 99
September . .	35	1 70	63	735	·254	7·62	5 11	— 2 51
October	40	1·46	72	·785	·172	5 33	7 82	+ 2 49
November . .	·45	2 63	77	·761	·157	4 71	4·95	+ 0 24
December .	29·49	2 40	73	·683	167	5 18	1·77	— 3 41
Annual .						95 73	33·58	—62 15

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
74. Negapatam.								
January	29 93	4 17	78	704	168	5 21	1 68	— 3 53
February	91	3 56	74	896	216	6 89	0 63	— 6 26
March	86	3 43	75	·800	205	6 36	0 34	6 02
April	80	3 62	79	·888	186	5 58	0 57	— 5 01
May	72	3 74	77	931	223	6 91	1 61	- 5 30
June	69	3 86	69	·841	309	9 27	1 30	— 7 97
July	71	3 49	71	819	260	8 06	1 89	— 6 17
August	73	2 94	76	854	194	6 01	3 59	- 2 42
September	76	2 70	78	867	169	5 07	3 77	1 30
October	81	2 39	81	859	133	4 12	10 48	+ 6 36
November	86	3 43	82	797	134	4 02	17 72	+ 13 70
December	29 90	4 54	79	712	168	5 21	11 40	+ 6 19
Annual						72 71	54 98	—17 73
75. Coimbatore.								
January .. .	28 62	1 54	75	605	117	3 63	0 59	— 3 04
February . .	60	1 48	69	608	·157	4 40	0 32	— 4 08
March .	55	1 48	66	651	·193	5 98	0 18	- 5 50
April . ..	·49	1 54	70	764	190	5 70	1 44	- - 4 26
May .	45	2 22	74	·796	183	5 67	2 36	— 3 31
June .	·41	3 58	73	739	221	6 63	1 66	— 4 97
July ..	42	3 83	74	·713	209	6 48	1 46	- 5 02
August .. .	·45	3 33	76	726	179	5 55	1 13	-- 4·42
September .. .	·47	2 78	77	·726	156	4 68	1 51	— 3 17
October . .	·51	1 48	80	·759	·109	3 38	6 41	+ 3 03
November	·56	1 30	82	712	·086	2 58	3 75	+ 1 17
December	28 60	1·48	79	·639	·098	3 04	1·18	— 1 86
Annual	..	..	..	..	..	57·72	22 27	—35·43

— —	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
76 Salem								
January	29 05	1 93	70	605	160	4 96	0 31	- 4 65
February	02	2 22	65	621	217	6 08	0 27	- 5 81
March	28 98	2 22	61	662	274	8 49	0 18	- 8 01
April	92	2 00	63	786	299	8 07	1 79	— 7 18
May	86	1 87	66	805	253	7 84	4 72	3 12
June	82	2 27	68	763	236	7 08	3 02	- 4 06
July	83	2 16	71	716	196	6 08	3 82	2 26
August	86	1 87	73	760	172	5 33	6 84	+ 1 51
September	89	1 53	74	762	154	4 77	6 59	+ 1 82
October	93	1 19	77	771	124	3 84	6 74	+ 2 90
November	28 98	1 30	78	716	111	3 33	3 74	+ 0 41
December	29 03	1 65	74	635	131	4 06	0 98	– 3 08
Annual						70 83	39 30	31 53
77 Madras								
January .	29 97	2 36	81	684	105	3 26	1 39	— 1 87
February .. .	93	2 07	79	692	114	3 19	0 32	– 2 87
March . .	88	2 53	78	794	151	4 68	0 19	— 4 49
April . ..	81	3 10	79	884	172	5 16	0 53	— 4 63
May ..	71	2 62	73	914	268	8 31	1 07	-- 7 24
June . .	67	3 68	65	·822	353	10 59	1 89	— 8 70
July .	68	3 16	72	828	239	7 41	3 94	— 3 47
August .	72	2 82	78	870	173	5 36	4 64	— 0 72
September .	75	2 41	80	895	148	4 59	4 99	+ 0 40
October ..	82	1 95	83	·877	110	3 41	11 72	+ 8 31
November . .	89	2 59	82	·785	·116	3·48	14 25	+10 77
December	29 95	2 93	79	·687	·127	3·94	5·81	+ 1 87
Annual	..	..	.	..	.	63·38	50·74	—12·64

	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches (5)	Mean Monthly Evaporation in inches (6)	Mean monthly Rainfall in inches (7)	Mean monthly Rainfall—Evaporation in inches (8)
78. Kurnool.								
January	29·05	1·67	56	·441	·204	6·32	0·18	— 6·14
February	·00	2·01	50	·455	·285	7·98	0·16	— 7·82
March ..	28·94	2·36	43	·481	·426	13·21	0·26	—12·95
April	·88	2·82	45	·612	·536	16·08	0·56	—15·52
May ..	·83	3·91	50	·684	·573	17·76	1·06	—16·70
June	·77	5·29	63	·724	·419	12·57	2·93	— 9·64
July	·77	5·29	71	·730	·293	9·08	4·80	— 4·28
August ..	·81	5·06	72	·726	·273	8·46	5·04	— 3·42
September ..	·85	3·39	73	·741	·214	6·42	6·17	— 0·25
October ..	28·92	1·73	68	·673	·189	5·86	3·47	— 2·39
November	29·00	1·38	65	·572	·172	5·16	1·14	— 4·02
December	29·05	1·27	62	·478	·160	4·96	0·24	— 4·72
Annual	..	..	..	..	..	113·86	26·01	—87·85
79. Cocanada.								
January	29·99	3·48	74	·563	·153	4·74	0·19	— 4·55
February	·94	3·04	74	·615	·156	4·37	0·32	— 4·05
March	·88	2·79	77	·756	·158	4·90	0·46	— 4·44
April	·80	3·16	80	·880	·163	4·89	0·56	— 4·33
May	·69	3·48	81	·999	·183	5·67	1·54	— 4·13
June	·60	3·73	79	·930	·199	5·97	4·81	— 1·16
July	·60	3·48	83	·899	·143	4·43	5·83	+ 1·40
August	·64	3·23	86	·929	·112	3·47	5·49	+ 2·02
September	·70	2·60	85	·943	·113	3·50	5·75	+ 2·25
October	·92	3·10	79	·835	·163	5·05	7·85	+ 2·80
November	·91	4·30	74	·664	·201	6·03	5·42	— 0·61
December	29·98	3·98	70	·533	·189	5·86	0·87	— 4·99
Annual	..	..	..	..	..	58·88	39·09	—19·79

—	Pressure (1)	Wind (2)	Humidity % (3)	Vapour Pressure (4)	Mean daily Evaporation in inches. (5)	Mean monthly Evaporation in inches (6)	Mean monthly Rainfall in inches. (7)	Mean monthly Rainfall—Evaporation in inches. (8)
50 Gopalpur								
January	29 97	3 92	65	517	228	7 07	0 23	— 6·84
February	90	4 87	66	597	284	7·95	0 69	— 7 26
March	82	6 27	66	704	389	12·06	0·54	—11·52
April	73	7 98	74	826	365	10 95	0·79	—10 16
May	62	7 98	77	939	355	11 01	1·97	— 9·04
June	50	6 77	79	930	281	8 43	5·82	— 2 61
July	50	5 70	83	931	195	6 05	6 88	+ 0·83
August	54	4 87	85	931	153	4 74	7 75	+ 3 01
September	64	4 18	84	924	150	4 50	7 51	+ 3·01
October	79	3 61	79	812	171	5 30	8 02	+ 2 72
November	90	3 92	73	638	194	5 82	4 02	— 1·80
December	29 97	3 92	69	500	184	5 70	0·74	— 4 96
Annual						89·58	44 96	—44·62

TABLE

Actual and Calculated

Month.	Pusa (1)		Madras (2)		Poona (3)		Bombay (4).	
	Actual	Cal	Actual	Cal	Actual.	Cal	Actual	Cal.
	(Inch.)	(Inch)	(Inch.)	(Inch)	(Inch)	(Inch)	(Inch)	(Inch)
January	07	05	15	10	23	27	24	24
February	10	08	18	11	33	30	25	27
March	16	21	20	15	46	41	29	27
April	22	33	25	17	73	59	33	28
May	26	33	27	27	65	46	39	27
June	20	18	29	35	35	29	17	23
July	16	10	24	24	32	17	11	21
August	14	10	23	17	21	14	13	18
September	13	11	18	·15	24	15	15	13
October	14	11	17	11	·26	18	·23	18
November	11	07	15	12	23	24	27	23
December	07	05	15	·13	·20	·22	26	24

(1) Evaporation from free water Surface by Dr Leather page 10

(3) Unpublished data collected at Agri Met. Observatory.

(5) Memoirs of Ind. Met Dept

(7) Unpublished data

3.

Values of Evaporation

Trivandrum (5).		Lahore, Lyallpur (6).		Sind, Sakrand, Hyderabad (7).		Karachi (8).	
Actual.	Cal.	Actual	Cal.	Actual.	Cal.	Actual.	Cal.
(Inch.)	(Inch.)	(Inch)	(Inch)	(Inch)	(Inch)	(Inch.)	(Inch)
11	12	07	05	18	19		·24
12	14	10	07	21	21		·26
13	15	16	·14	·26	36		·28
12	15	23	28	48	51		·23
11	14	29	43	73	69		24
08	08	37	44	76	67		28
08	10	31	28	64	55	27	26
09	11	27	26	48	43	27	·20
10	12	24	21	41	40	24	21
09	08	19	18	30	34	24	28
08	07	12	09	22	26	22	27
10	09	08	05	1[illegible]	21		26

(2) Observations at Madras observatory 1898-1903 India Met Dept.
(4) Q. J Roy Met Soc Volume XX (1894) page 63
(6) Evaporation from free water Surface by Dr. Leather
(8) Unpublished data

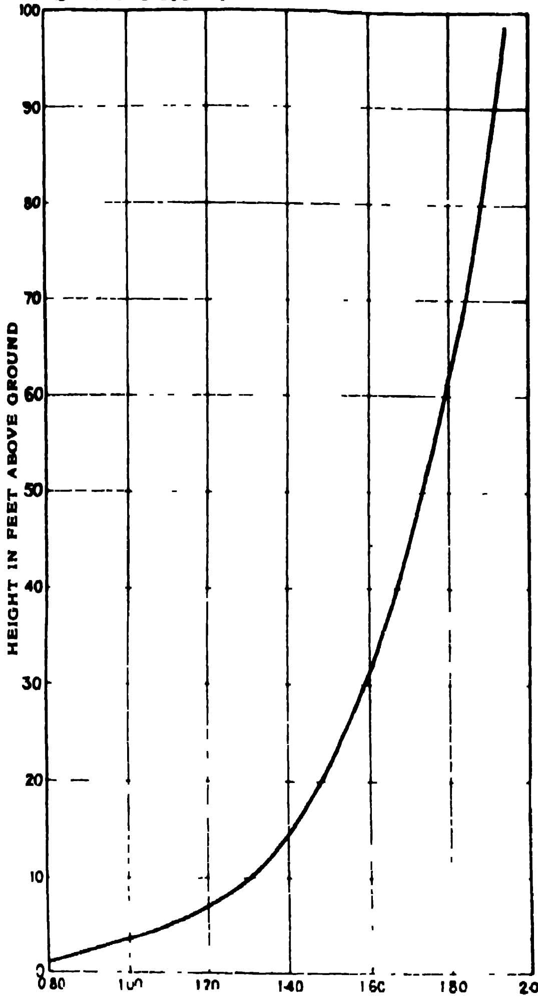


FIG 1 RATIO OF WIND AT ANY LEVEL TO WIND AT 4 FT LEVEL

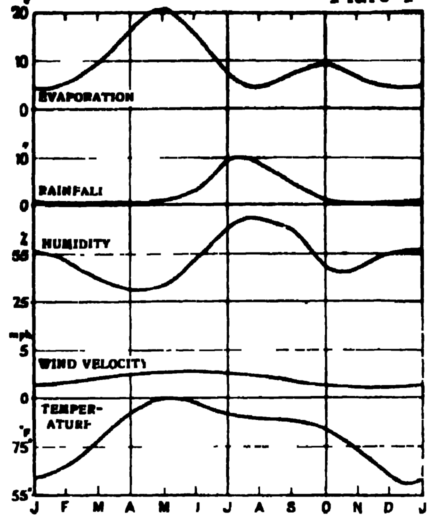
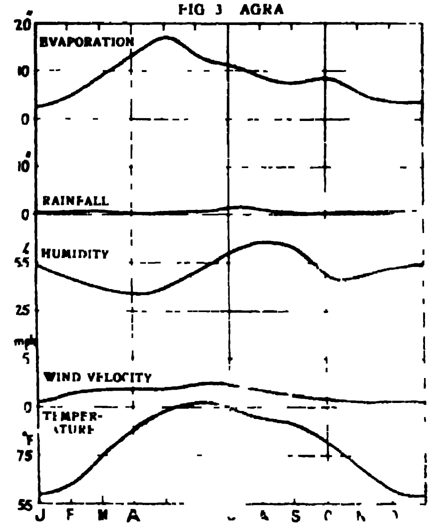


FIG 3 AGRA



[illegible]HAD

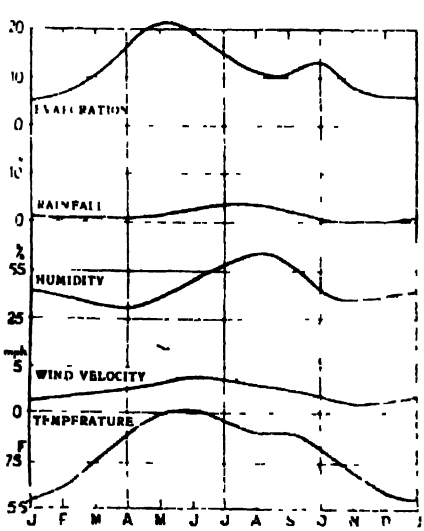


FIG 2 BIKANER

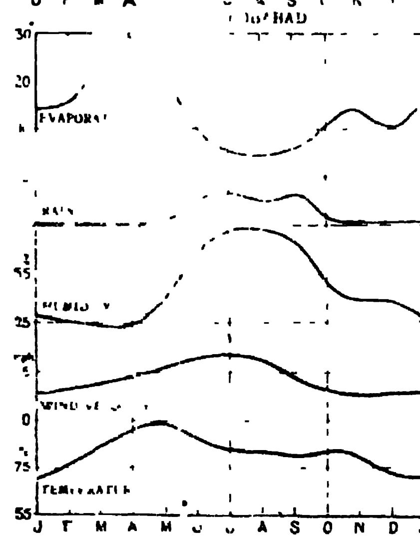


FIG 4 AURANGABAD

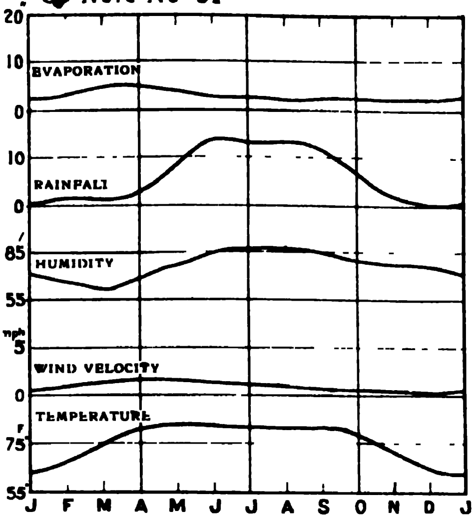


FIG 6 BOGRA

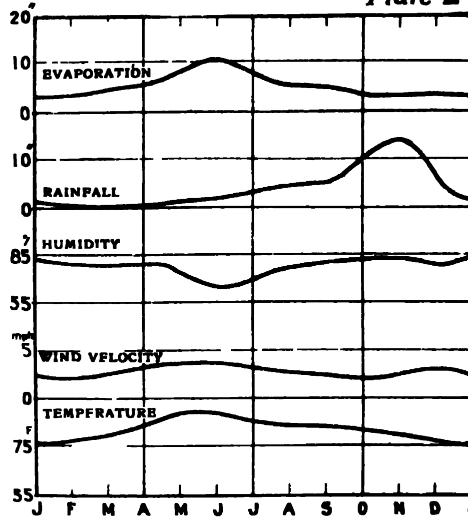


FIG 9 MADRAS

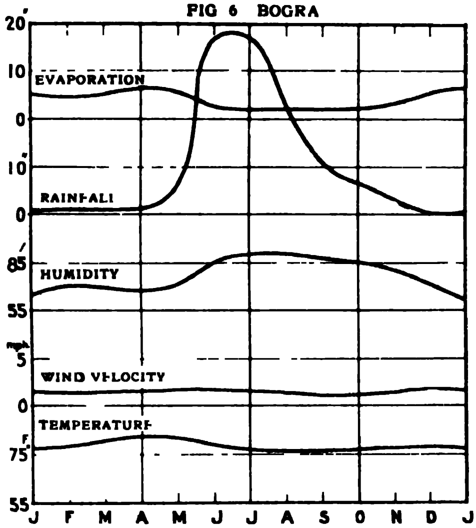


FIG 7 MANGALORE

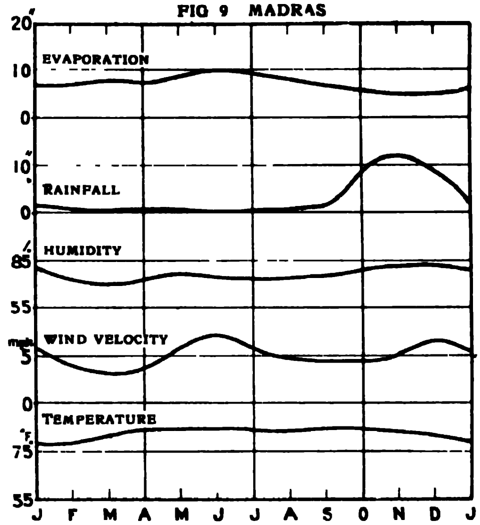


FIG 10 PAMBAN

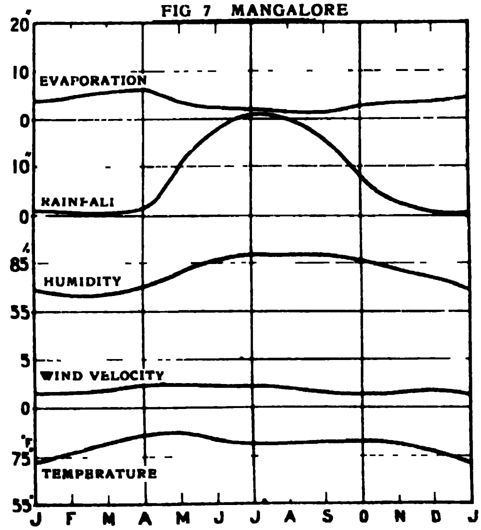


FIG 8 RANGOON

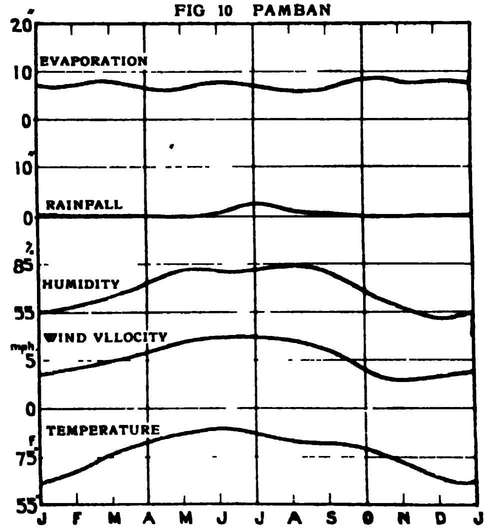


FIG 11 KARACHI

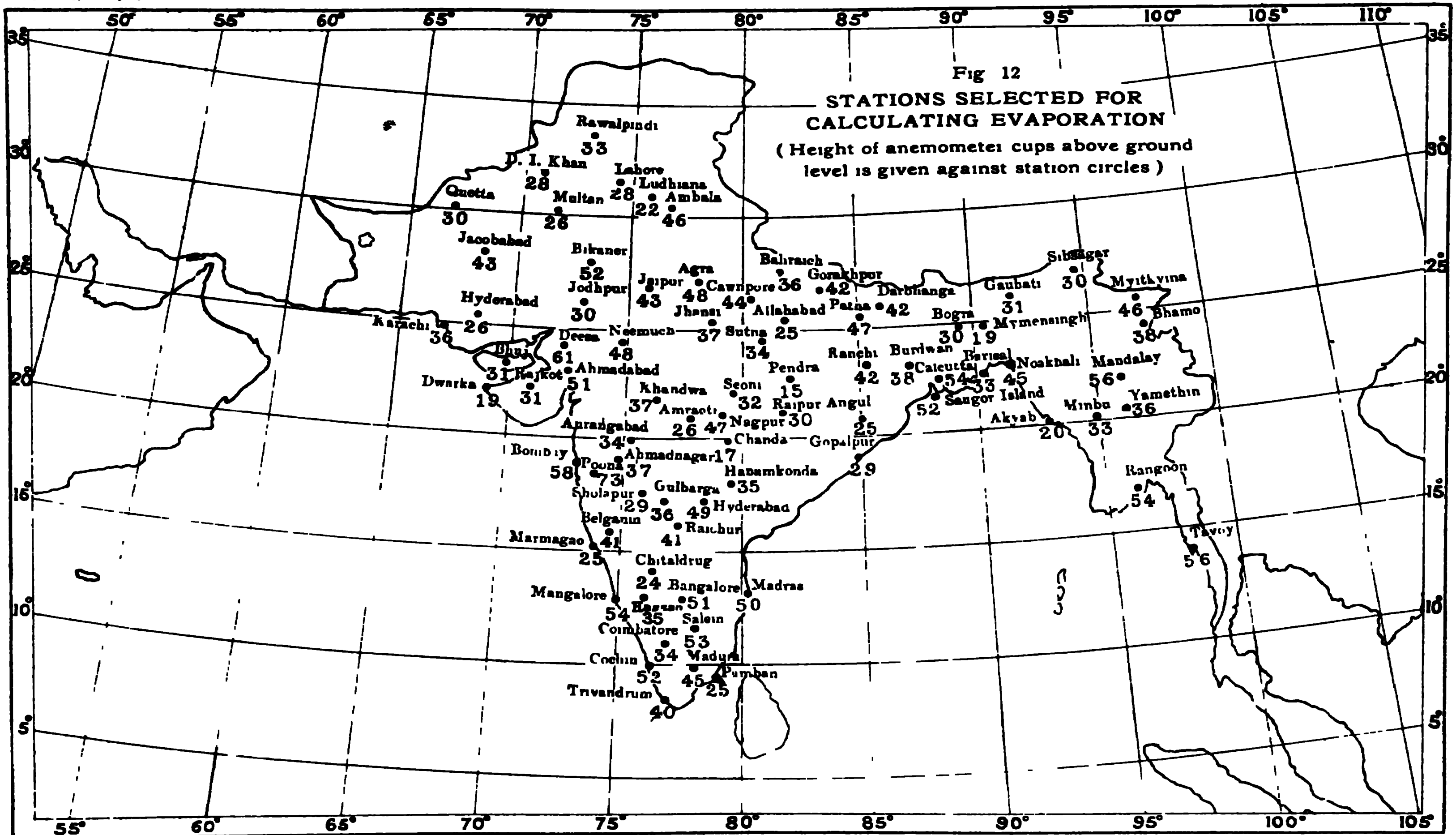


Fig 12

STATIONS SELECTED FOR CALCULATING EVAPORATION

(Height of anemometer cups above ground level is given against station circles)

G P Z O Poona, 19

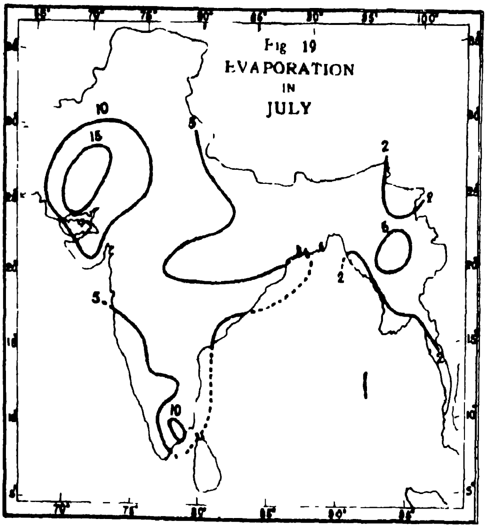


Fig 19
EVAPORATION
IN
JULY

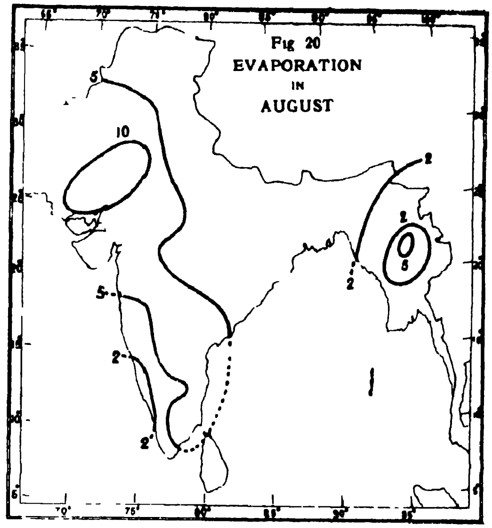


Fig 20
EVAPORATION
IN
AUGUST

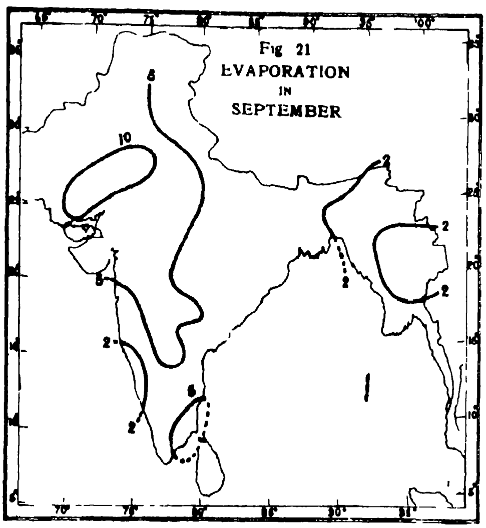


Fig 21
EVAPORATION
IN
SEPTEMBER

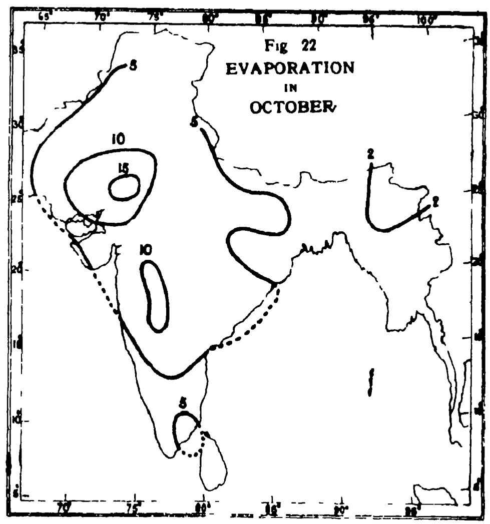


Fig 22
EVAPORATION
IN
OCTOBER

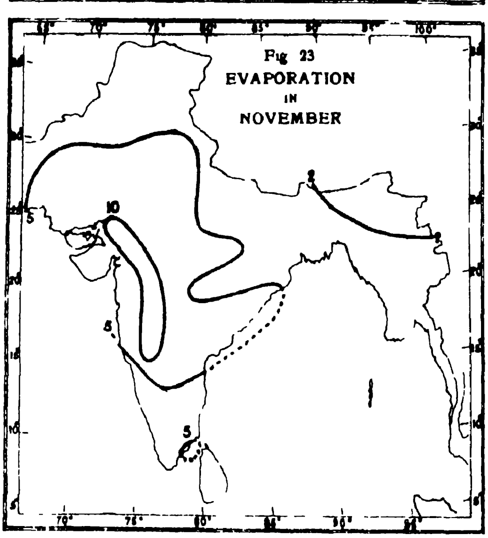


Fig 23
EVAPORATION
IN
NOVEMBER

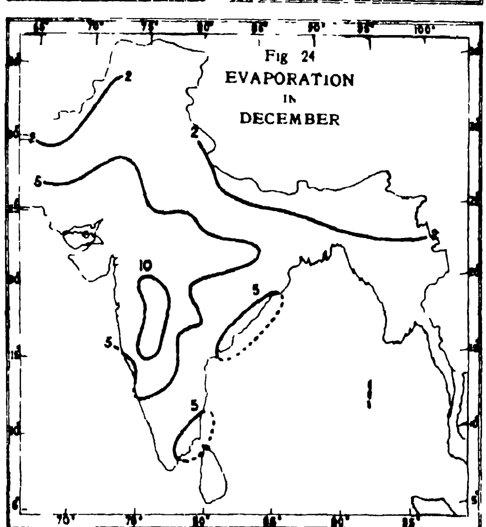


Fig 24
EVAPORATION
IN
DECEMBER

G P Z O POONA (19..)

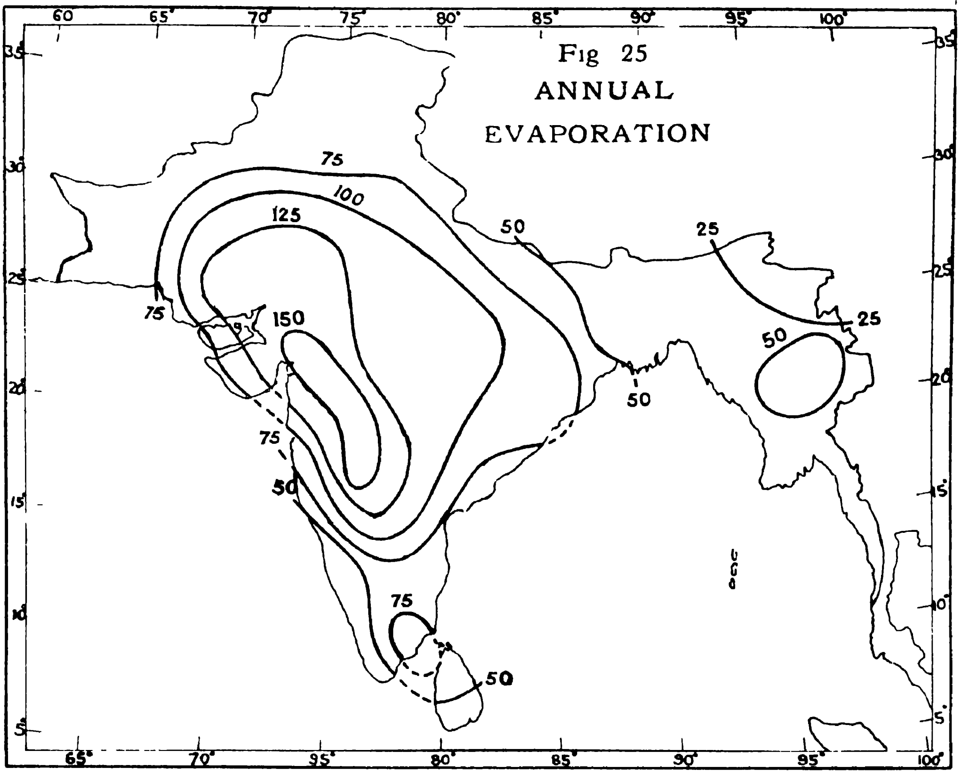


Fig 25
ANNUAL
EVAPORATION
75
100
125
150
75
50
25
25
50
50
75
50
75
50

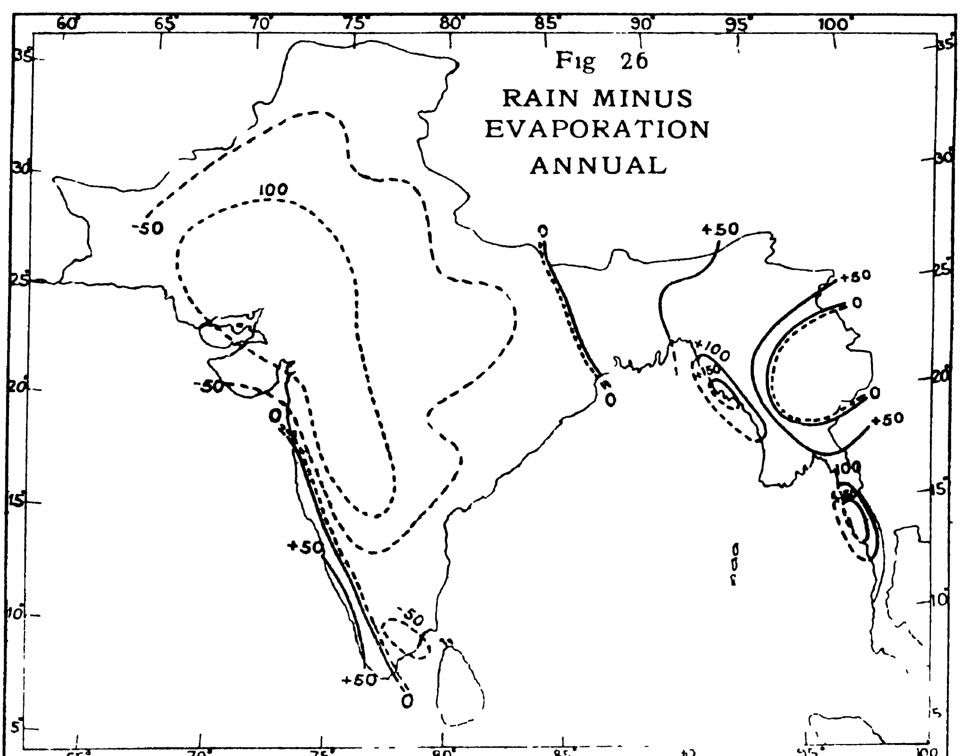


Fig 26
RAIN MINUS
EVAPORATION
ANNUAL
-50
100
0
+50
+50
0
-50
0
+50
50
+50
0
0
+100
+150
0
+50
100

A STUDY OF THE ATMOSPHERIC HORIZONTAL VISIBILITY AT BANGALORE

BY

A. ANANTHAPADMANABHA RAO.

(*Received on 17th May 1933.*)

Abstract—Visibility observations taken at Bangalore during a period of two years at 8, 10, 12 and 16hrs have been analysed and the monthly, seasonal and annual variation of visibility frequencies are given. Visibility is generally fair to good, bad visibility is a rare occurrence except in the mornings, when it is largely associated with mist, fog or haze; the frequency of bad visibility is greatest in winter and summer reaching a maximum in March, and is least in the SW monsoon with a minimum in August.

A study of the association of bad visibility with relative humidity, wind velocity, wind direction and Cumulus or Cumulo-Nimbus clouds, shows that—

(1) bad visibility is a minimum with values of relative humidity between 61 and 80%,

(2) frequency of bad visibility decreases with increase in the velocity of the surface-wind,

(3) bad visibility is most frequent with southerly winds and least frequent with northerly winds, and

(4) bad visibility is less frequent in the presence of Cumulus or Cumulo-Nimbus clouds than in their absence.

INTRODUCTION.

Topography—Bangalore, where the Central Observatory of the Mysore State is situated, is the chief administrative centre and lies in Lat 12° 58′N, Long 77° 37′E, at a height of 0·92 Kilometers above mean sea-level. It is far removed from the sea and is noted for its salubrious climate, extremes of temperature being unknown, and the atmosphere being neither very humid nor dry.

It covers an area of about 25 square miles, and is composed of two adjacent parts, the city and the Cantonment. It is not an industrial centre using coal on a large scale and the few mills and factories existing, which lie mostly to the west and northwest (see map) of the observatory, use electric power. The city Railway Station with its engines using coal is more than a mile away from the observatory. The atmosphere may therefore be expected to be largely free from pollution by products of combustion. Most of the roads with heavy traffic are tarred so that the dust raised by traffic is much less than in less favoured cities.

The Central Observatory is situated in the city area in a spacious compound in the midst of Government and University buildings.

Towards the northwest, north and east the surrounding country is open and undulating with hills rising in the distance. The chief of these are the Nandidurg (4850 ft.) at a distance of 32 miles to the north and the Sivaganga hills (4560 ft.) 30 miles to the northwest. Both of these are used as landmarks for visibility code figure 9. To the west and south the land slopes towards the valley of the Arkavati and is rocky and hilly. The hills are covered with thick jungle and numerous tributaries of the Arkavati rise from them Savandurga (4020 ft.) beyond the Arkavati at a distance of 20 miles to the west and the Banneraghatta hills (3270 ft.), 10 miles to the south are other land marks A map of Bangalore and surroundings, with a smaller map showing the observatory and mills, etc , is given as a frontispiece.

Data employed.—Visibility observations were made at 8, 10, 12 and 16 hrs Local Time, from the top of one of the turrets (54 ft) of the Central observatory in accordance with the International Code and have been denoted as usual by the Code figures 0 to 9 The data of the years 1930 and 1931 have been analysed. While considering the effect of wind on visibility at 8 hrs however, five years' data (from May 1927 to May 1932) have been used.

The data are discussed under two sections The monthly and seasonal as well as the diurnal variation of visibility are discussed in the first section. On account of the importance of the incidence of bad visibility for purposes of warnings to aviators, the second section deals mainly with the association of bad visibility with other meteorological elements.

SECTION I.—DIURNAL, MONTHLY, AND SEASONAL VARIATION OF VISIBILITY.

Table 1 gives the monthly frequencies of visibility under the different code figures, for the years 1930 and 1931 combined, for each hour of observation. Taking the year as a whole it will be seen that 80 per cent of the observations fall under the code figures 5, 6 and 7, and that only 9 per cent. fall under code figure 4. Lower visibilities are rare and hardly make up one per cent. At the other end of the scale, excellent visibility (code figure 9) constitutes 2 per cent. of the observations, and very good visibility (code figure 8), 9 per cent. Both of these are most frequent at 12 hrs , the next in order of frequency being at 10 hrs. ; this feature is present under code figure 7 also.

For the purpose of further discussion in this paper, the visibility observations have been classified under three groups as follows :—

(*a*) Code figures 0 to 4 termed bad, (*b*) Code figures 5 and 6 termed fair and (*c*) code figures 7 to 9 termed good

The percentage frequencies of bad, fair and good visibilities after such grouping, for each of the hours of observation, for each month, for the four seasons* and for the year as a whole are given in Table 2 The monthly variation of the percentage frequency of bad visibility is also shown in the polar diagrams in *Figure 1* for each of the hours.

This table also shows that visibility is generally fair or good at Bangalore and that the incidence of bad visibility is very small at hours other than 8 hrs. Bad visibility is a minimum at 12 hrs. when good visibility is a maximum. Though the frequency of bad visibility is the same at both 10 and 16 hrs. the frequency of good visibility is less at 16 than at 10 hrs.

*The four seasons of the year are —

(*a*) The cold season (December, January and February).
(*b*) The hot season (March to May).
(*c*) The southwest monsoon season (June to September), and
(*d*) The north east monsoon season (October and November).

Taking the year as a whole, 23 per cent. of observations shows bad visibility at 8 hrs. ; this proportion rises to 33 per cent. in the hot weather and to 35 per cent. in the cold season. The greater frequency of bad visibility in the cold season is no doubt due to the frequent occurrence of morning fog, mist and haze (see Table 3). These seem to dissipate, however, soon after 8 hrs as there are hardly any phenomena of this kind at 10 hrs , when the frequency of bad visibility is only 2 per cent. In the hot weather, on the other hand, the conditions which cause bad visibility seem to persist longer giving rise to 14 per cent. of bad visibility at 10 hrs. and 8 per cent. at noon The maximum frequency of bad visibility at 10 and 12 hrs. occurs in the hot weather At 16 hrs , however, the maximum frequency of bad visibility occurs in the southwest monsoon season and seems to be associated with the greater frequency of drizzle and rain at this hour, a feature which is present in other seasons also to some extent Considering the day as a whole, the maximum frequency of bad visibility occurs in the hot season and the minimum in the southwest monsoon season This appears to be due to the dusty and hazy condition in the hot season ; and the wet nature of the ground which prevents dust being raised after the rains set in Considering the months individually the maximum frequency of bad visibility occurs in March at all the hours, except 16 hrs when it occurs in June.

SECTION II - BAD VISIBILITY AND OTHER METEOROLOGICAL ELEMENTS.

(1) **Bad visibility and relative humidity at 8, 10 and 16 hrs.**—The percentage proportions of bad visibility to the total number of observations for different ranges of humidity at each of the hours 8, 10 and 16 are given in *Table 4* for the different seasons and also for the year. The annual figures are plotted in Figure 2.

Taking the year as a whole at each of the hours 8, 10 and 16 it is seen that as the humidity decreases from 100 per cent., there is a general tendency for the frequency of bad visibility to diminish down to a certain value of humidity, and then to increase with further decrease of humidity. Thus bad visibility is found to be least frequent for moderate values of humidity between 60 and 80%*.

A study of the percentage proportion of good visibility at 8 hrs. to the total number of observations for the same humidity ranges (*Table A*) shows a tendency opposite to that of bad visibility, *i.e.*, as the humidity decreases from 100%, frequency of good visibility increases to a maximum of 19% in the range 71 to 80% of humidity and decreases with further decrease of humidity.

TABLE A.

Variation of good visibility with humidity at 8 hrs, for 1930 and 1931.

Humidity %	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Total No of observations		.	2	7	16	23	91	249	294	48
No. of good visibility observations	.		.	.		3	10	58	51	2
Per cent of the above ..					.	13	11	19	17	4

Excellent visibility (Code fig 9) was recorded only 14 times during these two years, twice at 8 hrs and 12 times at 10 hrs. The corresponding humidity values ranged between 62 and 82%, except once in April when the humidity was 49%

*At very low humidities (below 40%) a second fall of bad visibility frequency can be suspected. But in most of these cases, the inference cannot be conclusive as the number of observations is very small.

The analysis of unusually good visibility at Valencia by Dines and Mulholland[1] shows that 80 per cent of the occasions was associated with relative humidities between 60% and 79% and that the percentage of unusual visibility rapidly decreased with increase of humidity, this is in agreement with the results at Bangalore. The above authors conclude that "dryness" of the air is of primary importance for unusual visibility, but it should be remembered, as the authors themselves point out, that "71% is approximately the mean value of the humidity at Valencia observatory at the driest hour of the driest month of the year" Again Bennett says that "very good visibility can only occur, however, in dry air[2]" and according to Wadsworth "The median visibility increases in value as the humidity of the surface air diminishes so that very dry air is usually associated with very good visibility"[3]

As already pointed out by Pick[4] these statements do not seem to be universally true. At Bangalore for example observations of visibility have been recorded at humidity values even below 10%, but good visibility has not been found to be associated with humidity below about 50%

These conclusions are also supported to a certain extent by the observations discussed by Barkat Ali[5] He finds that when humidity is above normal bad visibility is most frequent in all seasons except the hot season (March to May) when it is most frequent with humidity below normal *.

In a recent paper, A. K. Roy[6], has analysed the visibility observations at Quetta according to the different ranges of humidity On examining Table 6 and Fig 5 of the above paper, it is seen that the tendencies observed at Bangalore are also generally present at Quetta

The explanation for the tendencies observed is that with high humidities condensation of moisture present in the atmosphere on the nuclei occurs and with low humidities there is a tendency for the air to get dusty or hazy†. A contributing factor may also be an increase in the number of nuclei in the air

The data of *Table 4* are now examined statistically to test if the observed variation in frequency of bad visibility are really significant The observations are for this purpose classified under five groups, *i e*, 0-20%, 21-40%, etc (*Table B*). The standard error, $\sqrt{npq}$, where n=total number of observations of visibility in each group, p percentage frequency of bad visibility divided by hundred and q=1−p, is calculated for each group Then the range ($\pm$twice the standard error) within which the percentage frequency of bad visibility may vary accidentally is found for each group If any two ranges overlap, it means that the two are not significantly different

---

*The association between visibility and humidity at a place is more clearly exhibited when the analysis is made using actual ranges of relative humidity than by using criteria like 'above or below' normal, the physical conditions which cause condensation depend not so much, on the humidity being above normal as upon some critical value of relative humidity This value of humidity must be the same (or at least must lie within some range depending upon the supply of nuclei, etc), at all places

†Wadsworth's paper on 'The relation between Haze and Relative Humidity of the surface air" (Met. office, London, Vol 3. Prof Notes No 26, 1921) indicates a similar tendency at some of the places examined in England

‡H. L. Wright in his "Observations of smoke particles and condensation nuclei at Kew observatory" (Met. office. Geo. Mem. Vol 6 No. 57 page 17) has found high concentrations of nuclei both at very high and low humidities.

Table B.

Percentage frequency of bad visibility at 8, 10 and 16 hrs.

Groups	1	2	3	4	5	—
Humidity.	1—20%	21—40%	41—60%	61—80%	81—100%	
8 hrs		9	39	340	342	Total No. of observations.
	.	3	20	64	82	No of bad visibility
		64 0 to 2%	64 0 to 38 0%	23 0 to 14 6%	28 6 to 19 4%	Range of variation due to accident.
10 hrs	9	61	286	329	45	Total No of observations.
		10	16	6	9	No of bad visibility
		26·1 to 7 1%	8 7 to 3 3%	3 2 to 0 4%	32 0 to 8 0%	Range of variation due to accident.
16 hrs	61	222	286	114	47	Total No of observations
	3	8	13	5	16	No of bad visibility
	10 6 to 0 6%	6 5 to 1 5%	7 6 to 2 4%	8 3 to 0 5%	47 8 to 20 2%	Range of variation due to accident.

The following tendencies appear to be significant—

(1) At 8 hrs., bad visibility is less frequent in the 4th group than in the 3rd.

(2) At 10 hrs., bad visibility is less frequent in the 4th than either in the 3rd or 5th groups.

(3) At 16 hrs., bad visibility is less frequent in the 4th than in 5th group.

The second fall below 40% humidity is not significant at the hours 8, 10 and 16, as the ranges of variation in columns 2 and 3 overlap.

A similar analysis for good visibility at 8 hrs. (*Table C*) shows that good visibility in the 4th group is greater than in the 3rd group.

Table C.

Percentage frequency of good visibility at 8 hrs.

Groups	1	2	3	4	5	—
Humidity.	1—20%	21—40%	41—60%	61—80%	81—100%	
8 hrs		9	39	340	342	Total No of observations.
	.	0	3	68	53	No of good visibility
	..	0	14 9 to 0 5%	24 4 to 15 6%	19 9 to 12 1%	Range of variation due to accident

(2) **Bad visibility and the velocity of the surface wind at 8 hrs.** As already stated the data of five years have been utilised for this analysis. The velocity of the wind was determined by a Robinson Cup anemometer (cups being 54 ft. above ground level.) The percentage frequencies of bad visibility for different ranges of velocity at 8 hrs are given in *Table 5.* The diagram in *Fig. 3* indicates the same distribution for the year as a whole.

The table shows that in all seasons except the southwest monsoon season, the percentage frequency of bad visibility is high when the velocity is zero and that it gradually decreases as the velocity increases This general tendency to decrease with increasing wind velocity is also present in the southwest monsoon season, when the zero percentage with calms is probably due to the fact that five out of the six occasions were preceded by rainfall during the previous night The effect of wind is to disperse the dust particles and other condensation nuclei which are responsible for bad visibility This brings about a dilution of the suspended impurities so long as wind is not strong enough to raise fresh dust from the ground. That wind disperses the suspended impurities of the air is shown by the observations made by the Advisory Committee on Atmospheric pollution[7] it is found that the concentration of impurity varies inversely as the first power of the velocity of the wind except when the velocity is zero near zero, or when it exceeds a certain high value From the observations available at Bangalore we cannot definitely say that there is an increase of bad visibility after a critical value of the wind velocity, for there is only one case of bad visibility* out of eleven observations when the velocity of the wind was above 20 m p. h

The conclusions agree well with those of Barkat Ali[8] and Bennett[9] but according to Wadsworth[10], and Peck [11] a similar conclusion may not hold for sea-coast stations

(3) **Bad visibility and the direction of the surface wind at 8 hrs** — *Table 6* gives the monthly frequency of wind directions from the 16 points of the compass, with the corresponding frequency of bad visibility The data have also been grouped under the four quadrants N E, S, and W in the same table, the observations under the bordering directions NE SE, SW, and NW being equally divided between the adjacent quadrants The percentage proportion of bad visibility to the total number of observations for the year as a whole with winds from each of the 16 points of the compass is plotted in *Fig 4.*

The prevailing winds at Bangalore at 8 hrs are from the W and E quadrants, winds from the other quadrants being rare Wind directions lie almost wholly in the W quadrant in the southwest monsoon season and are to a great extent in the E quadrant in the cold season In other seasons there is a tendency for the wind directions to crowd around the above two quadrants

A study of the velocity of the winds from the different directions in the different months showed that winds from the W quadrant in the monsoon months are generally associated with high velocities and that west winds have a tendency to high velocities even in other months Winds from the E quadrant which generally prevail in the cold season are less pronouncedly associated with high velocities. In the remaining quadrants high velocities are less common and winds from these quadrants are mainly prevalent in the other seasons

Taking the year as a whole, the frequency of bad visibility with westerly winds is 8 per cent But it is found that 25 out of the 73 observations of bad visibility have occurred in March, if we omit these, the frequency will be reduced to 5 per cent The higher velocity of the surface winds, and the fact that they mainly occur in the rainy months when much dust cannot be raised from the ground probably explain the low frequency

Easterly winds are most prevalent in the months October to March and are practically absent from May to September The high percentage of bad visibility

*This case occurred on 2nd July 1930 with squally weather and overcast skies, the visibility being 4 at 8 hrs. The visibility at 8 hrs on the previous day was also 4 and the average wind velocity was high during the previous 48 hours.

with these winds seems therefore to be mainly due to their seasonal distribution as the cold season has more occasions of morning mist or fog.

Taking the year as a whole the frequency of bad visibility is a maximum, 21 per cent, with southerly winds, but 24 out of the 33 observations have occurred in March If we exclude this month, the frequency is reduced to 8 per cent.

The frequency of bad visibility with northerly winds, which are least frequent at Bangalore, is low, in spite of the fact that these winds occur mostly in the winter months This seems to indicate that during the incursion of cold winds from the north no dust or haze is allowed to remain over the city

The frequency of bad visibility is high in the month of March irrespective of the direction of the wind, the explanation for this probably lies in the fact that the variable and comparatively light winds in this month do not carry away the atmospheric pollution over Bangalore

(4) **Bad visibility and Cumulus or Cumulo-Nimbus cloud**--*Table 7* gives the percentage frequency distribution of bad visibility in the presence and in the absence of either of the above clouds at 8, 12 and 16 hrs for the four seasons of the year. It is seen that at each of the hours, bad visibility is less frequent on days with such clouds than on other days

This appears to be in agreement with the results of Wadsworth at Malta[12] and of Pick at Cranwell[13] As pointed out by the latter, the presence of the above clouds is a visible sign of convection currents, which help to improve visibility by diluting the dust particles and other suspended impurities in the lower air.

In conclusion, I wish to express my thanks to Mr C. Seshachar for allowing me the free use of the observatory records, to Prof A V Telang for his encouraging help, and to the officers of the Meteorological Department, Poona for valuable criticisms.

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11. Pick.—*See* discussion in Q. J. R. Met. Soc., Jan 1930., p. 28.

12. Wadsworth.—*Loc. Cit.*, p. 8.

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TABLE 1.

Distribution of visibility observations at 8, 10, 12 and 16 hrs. at Bangalore for 1930 and 1931.

Months	Hours	0	1	2	3	4	5	6	7	8	9	Total
January .	8	.		2	3	28	18	9	1	1		62
	10 .	.			..	1	12	39	8	2	..	62
	12						3	39	14	6		62
	16					.	31	26	5	..	..	62
February ..	8			1		18	25	9	3	.	..	56
	10					1	20	24	9	2	..	56
	12					.	5	26	24	1	..	56
	16	.				3	26	22	5	.	..	56
March ..	8				9	39	11	2	1	..	..	62
	10	..		..		17	26	18	1	.	..	62
	12			..	.	11	14	17	18	2	..	62
	16	..	.	..	..	1	44	16	1	.	..	62
April ..	8	..	..	..	1	9	27	14	7	2	..	60
	10	..	..		..	6	8	22	19	4	1	60
	12	..	..	..	.	2	4	31	17	2	4	60
	16	..	..	.	..	2	7	34	12	1	4	60
May ..	8	..	..	..	..	3	28	14	10	7	..	62
	10	..	..	..	..	3	8	27	13	8	3	62
	12	..	..	..	1	.	3	20	17	15	6	62
	16	..	..	..	..	8	22	20	11	1	..	62
June ..	8	..	..	..	2	2	14	18	14	10	..	60
	10					2	12	15	14	13	4	60
	12		..	.	.	3	3	13	20	18	3	60
	16	..	..	.	..	14	13	17	13	3	..	60

TABLE I—*contd.*

Distribution of visibility observations at 8, 10, 12 and 16 hrs. at Bangalore for 1930 and 1931—contd.

Months	Hours	0	1	2	3	4	5	6	7	8	9	Total.
July ..	8			.		9	29	18	6	..	..	62
	10					2	8	31	15	6	..	62
	12		.			1	6	22	24	9	..	62
	16					3	22	29	8	.	.	62
August .	8		.	.		6	28	16	9	3	..	62
	10			.			7	32	18	5	..	62
	12					.	2	28	23	9	..	62
	16			..			27	30	4	1	..	62
September	8				1	4	14	19	17	4	1	60
	10					1	4	12	27	15	1	60
	12					2	4	13	23	16	2	60
	16				1	6	30	12	8	3	.	60
October	8				1	9	23	16	8	4	1	62
	10					3	6	22	18	11	2	62
	12				.		2	12	21	25	2	62
	16					2	18	22	14	6	..	62
November	8					9	24	15	10	2	..	60
	10					2	9	20	15	13	1	60
	12				1	2	2	21	8	19	7	60
	16				2	2	17	18	18	3	.	60
December	8					11	32	14	5	.	..	62
	10		..			2	12	29	16	3	..	62
	12			.		1	4	20	21	13	3	62
	16		.	.		1	15	32	11	3	..	62
Year (1930 and 1931)	8	..		3	17	147	273	164	91	33	2	730
	10	..				40	132	291	173	82	12	730
	12	..	..		2	22	52	262	230	135	27	730
	16		.	.	3	42	272	278	110	21	4	730
Total ..	All hours		..	3	22	251	729	995	604	271	45	2920

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TABLE 2.

The relation between bad, fair and good visibility observations and the hour of the day in the different months of the year.

Months	Total no. of observations	Type	Percentage frequencies at— 8	10	12	16	All hours combined.
January ..	62	Bad	53	2			14
		Fair	44	82	68	92	71
		Good	3	16	32	8	15
February	56	Bad	33	2		5	10
		Fair	62	78	54	86	70
		Good	5	20	46	9	20
Cold season	180	Bad	35	2	0	2	10
		Fair	59	76	54	85	68
		Good	6	22	46	13	22
March	62	Bad	77	27	8	2	29
		Fair	21	71	60	96	62
		Good	2	2	32	2	9
April	60	Bad	17	10	3	3	8
		Fair	68	50	58	68	61
		Good	15	40	39	29	31
May ..	62	Bad ..	5	5	2	13	6
		Fair ..	67	56	37	67	57
		Good	28	39	61	20	37
Hot season	184	Bad ..	33	14	8	6	15
		Fair ..	52	59	48	78	60
		Good ..	15	27	44	16	25

TABLE 2—*contd.*

The relation between bad, fair and good visibility observations and the hour of the day in the different months of the year—contd.

Months.	Total no. of observations.	Type.	Percentage frequencies at— 8	10	12	16	All hours combined
June .. .	60	Bad .	7	3	5	23	9
		Fair	53	45	26	50	43
		Good	40	52	69	27	48
July	62	Bad .	15	3	2	5	6
		Fair ..	75	63	45	82	65
		Good	10	34	53	13	29
August . .	62	Bad	10				3
		Fair	69	63	48	92	68
		Good	21	37	52	8	29
September ..	60	Bad	8	2	3	11	6
		Fair .	55	26	29	71	45
		Good	37	72	68	18	49
SW Monsoon season	244	Bad ..	10	2	2	10	6
		Fair .	64	50	37	74	56
		Good ..	26	48	61	16	38
October	62	Bad ..	16	5		3	6
		Fair ..	63	45	22	65	41
		Good	21	50	78	32	53
November .	60	Bad ..	15	3	5	7	7
		Fair ..	65	47	38	58	52
		Good	20	50	57	35	41
NE Monsoon season	122	Bad ..	16	4	2	5	7
		Fair ..	64	46	31	61	50
		Good ..	20	50	67	34	43
December ..	62	Bad .	18	3	2	2	6
		Fair ..	74	66	38	75	63
		Good ..	8	31	60	23	31
Year	730	Bad ..	23	6	3	6	9
		Fair ..	58	57	43	76	54
		Good ..	19	37	54	18	37

TABLE 3.

Monthly frequencies of fog, mist, rain, drizzle and haze at 8, 10, 12 and 16 hrs. for 1930 and 1931.

Weather	Hours	January	February	March	April	May	June	July	August	September	October	November	December.	Year.
Rain	8					1				2		1		4
	10					2						1		3
	12					1		2	1			1		5
	16					4		5	1	1	2	1		14
Drizzle	8	.				1	3	4	1	2	3	2	5	21
	10	.				1	1	2	3	1	4	2	2	16
	12					1		1	2		6	1	1	12
	16	1				4	3	4	2	3	6	3	2	28
Fog .	8	7	1					.						8
	10												..	0
	12													0
	16													0
Mist .. .	8	10	6	1		1	1				3	2	2	26
	10								.		.			0
	12	.									.	..		0
	16												.	0
Haze	8	8	1	2	3	14			..	..		..	7	35
	10	1	.	.		.	.	.	.	.	..	..	..	1
.	12	..	.	2	1	..	..	..	.	..	..	..	..	3
	16	..	..	1	.	..		..	..	.		..	..	1

Table 4.

Seasonal variation of frequency of bad visibility with humidity at 8, 10 and 16 hrs.

Season	Humidity (%)	0—10	11—20	21—30	31—40	41—50	51—60	61—70	71—80	81—90	91—100	Hours.
Cold season	Total			2	1	3	4	21	58	77	14	
	% of bad			0	0	0	25	29	33	38	50	
Hot season	Total				6	11	16	64	66	18	3	
	% of bad				50	55	69	34	23	17	33	
SW Monsoon season	Total						2	3	87	133	19	8
	% of bad						50	0	1	11	47	
NE Monsoon season	Total					2	1	3	38	66	12	
	% of bad					50	0	0	3	14	67	
Year .	Total			2	7	16	23	91	249	294	48	
	% of bad			0	43	44	57	31	14	19	52	
Cold season	Total		4	9	15	39	53	33	18	7	2	
	% of bad		0	0	0	3	0	3	6	0	50	
Hot season	Total		5	14	20	58	63	15	5	3	1	
	% of bad		0	36	25	16	6	0	0	67	100	
SW Monsoon season	Total					3	45	111	73	11	1	10
	% of bad					0	2	0	4	9	0	
NE Monsoon season	Total				3	6	19	12	32	17	3	
	% of bad				0	17	0	0	3	6	100	
Year	Total		9	23	38	106	180	201	128	38	7	
	% of bad		0	22	13	10	3	0	4	11	71	
Cold season	Total	2	23	15	30	41	13	15	6	3	2	
	% of bad	0	9	2	0	0	0	0	0	0	0	
Hot season	Total	1	35	83	34	16	7	3	2	3		
	% of bad	0	3	0	12	13	14	0	50	67		
SW Monsoon season	Total				20	90	60	35	18	19	2	16
	% of bad ..				15	8	5	6	11	32	50	
NE Monsoon season	Total .				10	27	32	20	15	11	7	
	% of bad .	.			0	0	0	0	0	18	57	
Year ..	Total . ..	3	58	128	94	174	112	73	41	36	11	
	% of bad .	0	5	1	7	5	4	3	7	28	55	

TABLE 5.

Frequencies of bad visibility for different velocities of surface wind at 8 hrs. in the different seasons.

Velocity in miles per hour	Cold season.		Hot season.		SW Monsoon season		NE Monsoon season.		Year	
	Total No of observations	% frequency of bad visibility	Total No of Observations	% frequency of bad visibility	Total No of observations	% frequency of bad visibility	Total No of observations	% frequency of bad visibility	Total No of observations	% frequency of bad visibility.
Calm	13	62	17	29	6	0	5	20	41	34
1—5 . .	140	28	201	25	37	8	95	17	473	23
6—10 . .	259	15	227	16	269	6	177	3	932	10
11--15 .. .	16	2	37	0	203	2	132	1	318	2
16—20	7	0	16	0	91	2	1	0	115	2
Over 20	0	..	0	..	11	10	0	.	11	10

TABLE 6.

Frequency of wind directions with the corresponding frequencies of bad visibility at 8 hrs.

—	January	February	March	April	May	June	July.	August	September	October	November	December.	Year.
NW	1	1	1	2	4	1	.	1	5	3	1		20
	0	***0***	***0***	***1***	***0***	***0***		***0***	***1***	***0***	***1***	.	***3***
NNW	1	1			4	.					2		8
	0	***0***	.		***0***	.		.			***0***		***0***
N	..	1	.	..	.		..	.	2		1	.	4
	.	***0***	.		..		.		***1***	.	***1***	.	***2***
NNE	3	1							2	10	7	7	30
	0	***0***	.	.	.	..	..		***0***	***0***	***0***	***0***	***0***
NE	10	3	1	.	2	.	..	.	.	6	23	15	60
	1	***1***	***0***		***0***	.				***1***	***0***	***0***	***3***
N Quadt.	15	7	2	2	10	1	.	1	9	19	34	22	122
	1	***1***	***0***	***1***	***0***	***0***		***0***	***2***	***1***	***2***	***0***	***8***
NE	10	4	1	1	2	.			.	6	23	16	63
	2	***1***	***0***	***0***	***0***				.	***1***	***1***	***1***	***6***
ENE	51	18	8	3	1				..	28	50	66	225
	14	***5***	***0***	***1***	***0***				.	***0***	***0***	***9***	***29***
E	55	32	23	3	5				2	12	22	36	190
	13	***2***	***7***	***0***	***0***				***0***	***1***	***4***	***5***	***32***
ESE	11	38	14	5					1	5	5	9	88
	3	***4***	***5***	***0***					***0***	***2***	***0***	***1***	***15***
SE	1	10	9	9						2	2	..	33
	1	***1***	***1***	***0***		.		.		***0***	***0***	..	***3***
E Quadt.	218	102	55	21	8				3	53	102	127	599
	33	***13***	***13***	***1***	***0***	..			***0***	***4***	***5***	***16***	***85***

N.B.—Figures in Roman type represent the frequency of wind direction, figures in bold Italics the frequency of bad visibility.

TABLE 6—*contd.*

Frequency of wind directions with the corresponding frequencies of bad visibility at 8 hrs —contd.

—	January	February	March	April	May	June	July	August	September	October	November	December	Year
SE . . .	2	11	9	9	1					2	3	1	38
	1	***1***	***2***	***0***	***0***					***1***	***0***	***0***	***5***
SSE	1	2	12	5					.	1	.		21
	1	***0***	***6***	***0***				.		***0***		..	***7***
S .. .	1	2	12	8					3	2	.		28
	0	***0***	***4***	***0***					***0***	***0***	..	.	***4***
SSW	2	4	8	10	1				1	1	3	1	31
	0	***1***	***7***	***1***	***0***				***0***	***0***	***0***	***1***	***10***
SW		2	6	5	7	7	6	4	3	4		.	44
		1	***5***	***1***	***0***	***0***	***0***	***0***	***0***	***0***	.	.	***7***
S Quadt .	6	21	47	37	9	7	6	4	7	10	6	2	162
	2	***3***	***24***	***2***	***0***	***0***	***0***	***0***	***0***	***1***	***0***	***1***	***33***
SW	.	2	7	5	7	7	6	5	3	4	..	..	46
	..	***1***	***5***	***2***	***1***	***0***	***1***	***1***	***0***	***1***	..	..	***12***
WSW .	1	1	18	28	35	64	76	52	22	22	1	1	321
	0	***0***	***10***	***2***	***1***	***3***	***4***	***2***	***1***	***3***	***1***	***1***	***28***
W . .	1	2	15	32	81	58	58	65	59	34	..	.	405
	0	***0***	***10***	***6***	***1***	***1***	***2***	***3***	***1***	***2***	..	.	***26***
WNW .. .		1	2	17	21	13	8	28	38	8	3	.	139
		0	***0***	***1***	***1***	***0***	***2***	***1***	***1***	***0***	***1***	..	***7***
NW . .				2	3				5	3	1	..	14
				0	***0***				***0***	***0***	***0***	.	***0***
W Quadt .. .	2	6	42	84	147	142	148	150	127	71	5	1	925
		1	***25***	***11***	***4***	***4***	***9***	***7***	***3***	***6***	***2***	***1***	***73***
Calm . ..	4	6	9	6	2		1		5	2	3	3	41
	3	***2***	***5***	***0***	***0***	.	***0***	..	***0***	***0***	***1***	***3***	***14***

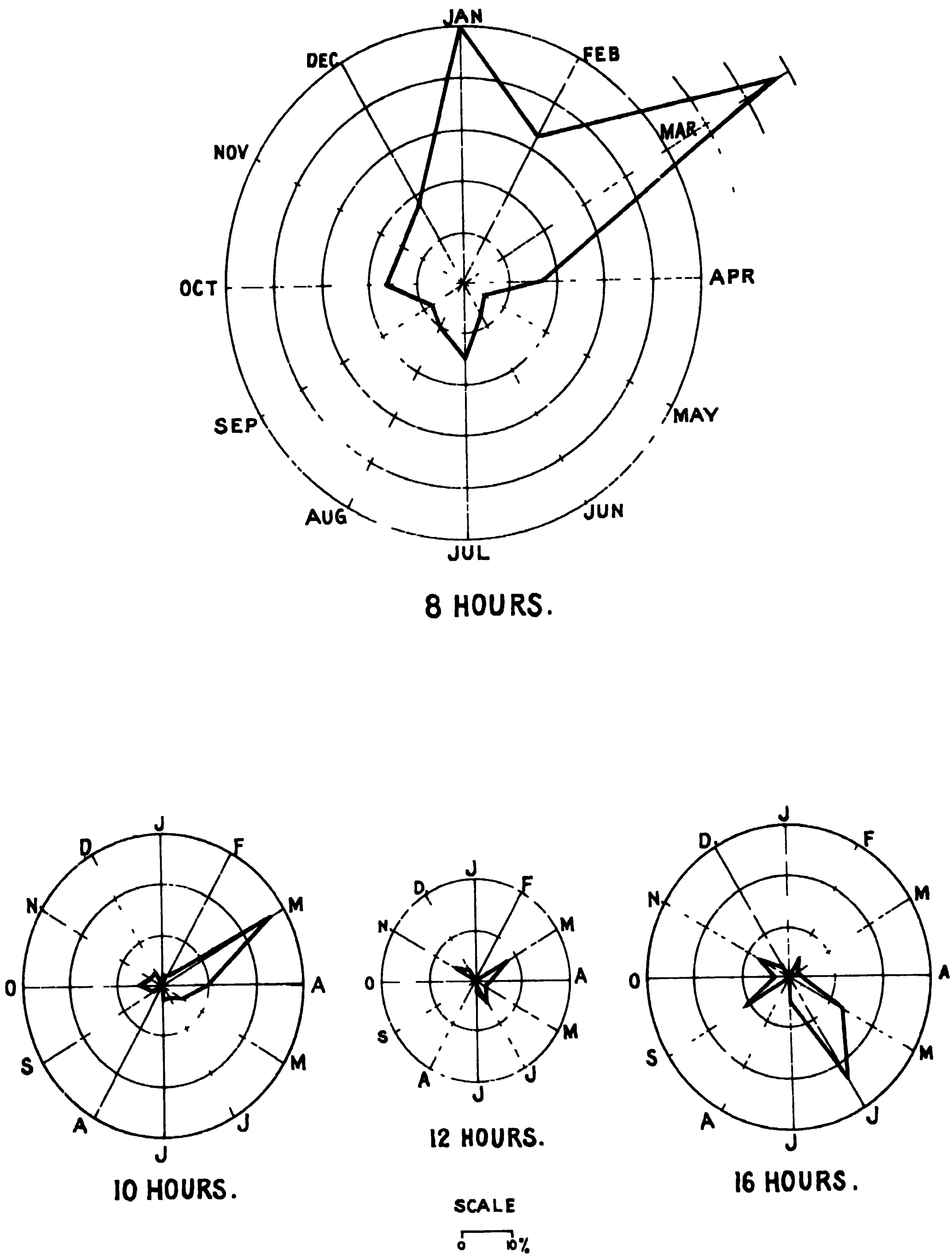
N.B.—Figures in Roman type represent the frequency of wind direction; figures in bold Italics, the frequency of bad visibility.

TABLE 7.

Relation between visibility and Cumulus or Cumulo-Nimbus clouds in the different seasons and at different hrs.

Seasons.	Days with convection clouds: Total No of observations	Days with convection clouds: No of occasions of bad visibility	Days with convection clouds: % frequency of bad visibility	Days without convection clouds: Total No of observations	Days without convection clouds: No of occasions of bad visibility	Days without convection clouds: % frequency of bad visibility	Hours.
Cold	58	16	27	122	47	39	
Hot	58	11	19	126	50	40	
SW Monsoon	143	11	8	101	13	13	8
NE Monsoon .. .	51	7	14	71	12	17	
Year .	310	45	15	420	122	29	
Cold	67	0	0	113	1	1	
Hot	80	2	3	104	12	12	
SW Monsoon	207	5	2	37	1	3	12
NE Monsoon	98	3	3	24	0	0	
Year	452	10	2	278	14	5	
Cold	65	1	2	115	3	3	
Hot	116	6	6	68	5	7	
SW Monsoon	208	20	10	36	4	11	16
NE Monsoon	83	2	2	39	5	13	
Year ..	472	29	6	258	17	7	
Cold	190	17	9	350	51	15	
Hot	254	19	8	298	67	26	
SW Monsoon	558	36	8	174	18	10	All hours.
NE Monsoon	232	12	5	134	17	13	
Year ..	1,234	84	7	956	153	16	

M15DGofOb—1—3-1-36—GIPS


JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
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8 HOURS.
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D
10 HOURS.
12 HOURS.
16 HOURS.
SCALE
0
10%

FIG. 1.

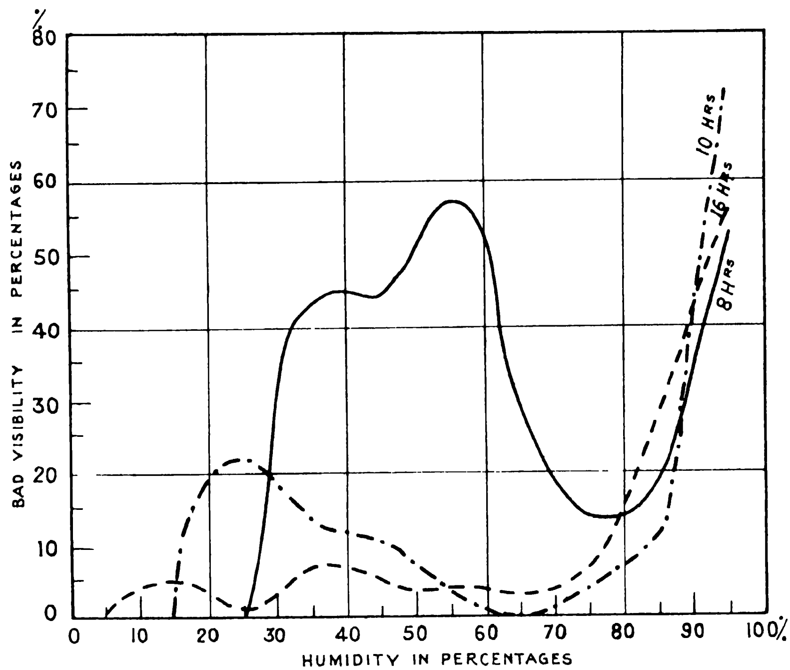

FIG. 2. HUMIDITY & BAD VISIBILITY.

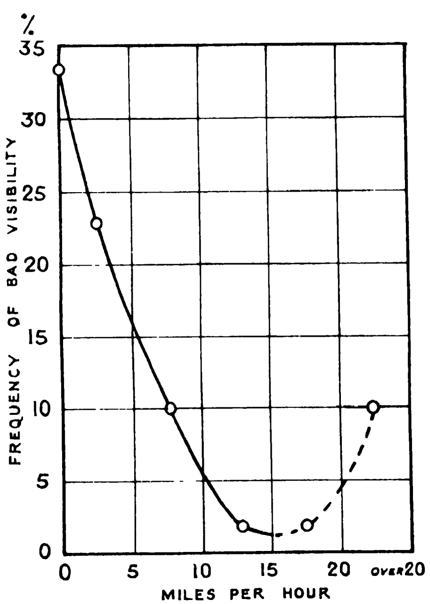

FIG. 3. WIND VELOCITY & BAD VISIBILITY.

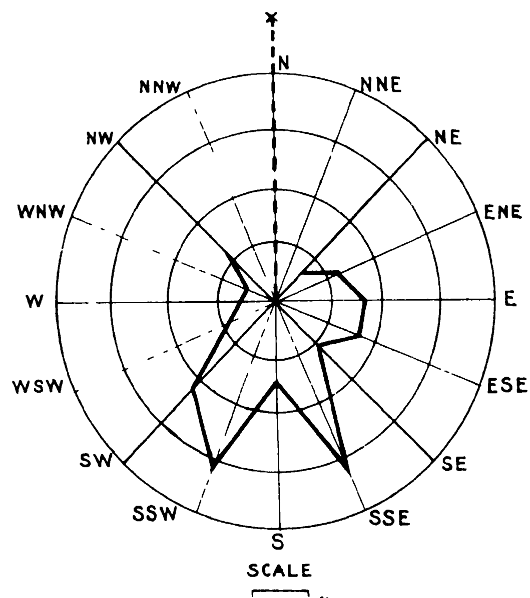

FIG. 4. WIND DIRECTION & BAD VISIBILITY.

G P Z O Poona, 1934

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A Statistical Study of the Maximum Temperatures at Poona

BY

R. J. KALAMKAR, B.Sc., B.Ag, Ph.D.

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A STATISTICAL STUDY OF THE MAXIMUM TEMPERATURES AT POONA*

BY

R. J. KALAMKAR, B Sc., B Ag, Ph D

(*Received on 11th September 1933*)

Abstract This paper deals with the analysis of Maximum Temperature at Poona from 1880 to 1931 The coefficient of variability of mean monthly maximum temperature is comparatively higher for June and October which are characterised by the setting in and withdrawal respectively of the southwest monsoon The values of the correlation coefficients for the neighbouring months of autumn and winter are high Regression equations for forecasting temperatures for the five seven day periods *viz*, November 27 December 3rd, December 4th December 10th December 11th—December 17th, December 18th- December 24th, and December 25th December 31st are obtained from the weekly temperatures of the preceding four weeks.

Temperature is one of the important weather elements controlling the growth and yield of crops It may have its influence either directly by affecting the physiological process or indirectly by the spread or inhibition of plant diseases or by the interaction of both in a variety of ways

Forecasts of temperature, especially of heat and cold waves, would be of great use to farmers in carrying out their farming operations. For instance, an enquiry was made by the Plant Pathologist to the Government of Bombay regarding the possibility of forecasting maximum temperature for the month of December in Kaira District, as it is the most potent factor in influencing the development of Cumin Mildew.

It is desirable in the first instance to know how the temperatures at a single station are associated in successive periods of time and what degree of interdependence underlies them. As a preliminary, the maximum temperature at Poona was selected for such an investigation The data for the 52 years from 1880 to 1931 have been used in the present analysis

The average maximum temperature for the different months for the above period of 52 years were first tabulated and the means and the standard deviations were worked out therefrom. The results are set out in the *Table* below.

---

*The present investigation was made in the Agricultural Meteorology Branch (India Meteorological Department) financed by the Imperial Council of Agricultural Research.

TABLE I.

Average Maximum Temperature (Degrees F.)

	Jan.	Feb.	March	April.	May.	June	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Maximum Temp.	86·4	90·6	97 3	101·2	99 8	90 0	82 6	81 8	84·6	89·2	86·7	84·8
Standard Deviation.	1·73	1 84	1 86	2 14	1·83	2·70	1·74	1·46	1 90	2·83	1·83	1·98
Coeff. of variability	2·00	2·03	1·91	2·11	1·83	3·00	2 11	1·78	2 24	3·17	2·11	2·33

It will be observed from the above *Table* that there are two maxima, one in the month of April and the other in the month of October, that in April being higher. The lowest values are found, not in the winter months, but in the months of July, August and September, when the monsoon is most active and skies are heavily clouded. The coefficient of variability is highest for the months of June and October, the former is the month in which the monsoon usually sets in and the latter the month of its withdrawal, and the variations in the dates of setting in and withdrawal of the monsoon probably explain the high variability.

The average maximum temperatures for the different months over the period of 52 years were plotted with a view to detect the presence of any secular trend. The graphs showed in general the absence of any secular trend except perhaps for the months of January and February, which were then subjected to a statistical analysis by fitting a polynomial of the fifth degree([1]). The analysis showed the absence of any long time trends as judged by the comparison of the values of x's with their standard deviation.

TABLE II.

Secular trends in the values of maximum temperature for the months of January and February.

January.		February.	
x'_2	1·175	x'_2	—2 449
x'_3	—0 064	x'_3	0 183
x'_4	0·573	x'_4 . ..	0·621
x'_5	0·283	x'_5	—0·233
x'_6	—0·097	x'_6	—0·032
S. D.	1·82	S. D.	2·01

An attempt was next made to study how the maximum temperature in any one month is related to that in the other months. In addition to the correlations between the month of the same year, correlations were worked out between September, October, November and December of one year and January, February March and April of the succeeding year. The values of the correlation coefficients for the different months are given in *Table III* below.

TABLE III.

Correlations between successive months.

	Jan.	Feb.	Mar	Apr	May.	Jun.	Jul.	Aug.	Sep	Oct.	Nov.	Dec.
Feb.	·45											
March	·54	·40										
April .. .	·25	·35	·40									
May . .	·34	·31	·25	·35								
June ..	·09	·10	·09	·03	·40							
July	·12	18	— 04	·03	·16	·29						
Aug. .. .	—·09	·10	·25	·00	— 09	—·14	·14					
Sep.	—·07	·03	·10	—·04	·00	·08	·18	·10				
Oct.	—·06	·00	·12	—·12	—·05	·00	·07	—·03	·51			
Nov.	—·06	·00	·02	—·22	—·01	·17	·21	·03	·57	·91		
Dec.	·19	—·04	·22	— 02	·08	·04	·02	·00	·42	·61	·85	
Jan.									·23	·51	·58	·51
Feb.										·29	·33	·27
March											·55	·27
April												·17

According to Fisher's Table V (A) in (2) the values of the correlation coefficients for 5 and 1 per cent level of significance for 50 degrees of freedom are ·27 and ·35 respectively. It will be observed that out of the 76 correlations 24 exceed the 5 per cent point. The values of the correlation coefficients between the successive months are significant except in the monsoon months June to September. Using Walker's criteria extended by Savur and Gopal Rao, (3) however, the 5 per cent. chance highest value of 'r' in a group of 76 correlations is ·48. On this criterion even the fairly high correlation coefficients between successive months January to May are not significant. Significant correlations are found in the months September to December between successive months as well as between one month and the second or third succeeding month. This indicates that the winter months are strongly correlated with each other. The explanation for this is probably to be sought in the calm clear days of Poona winter contributing, so to say, to a summation process or 'carry over'. A preliminary analysis of the maximum temperatures at a few other stations in India which is in hand shows interesting relations between the periods of high inter-monthly correlation coefficients and the seasonal change in weather.

The high correlations of the winter months, October to December suggested an extension of the investigation to smaller periods of time, as a forecast of mean maximum temperature of such a long period as a month will not be of practical utility to farmers. It is not possible on the other hand to make the period very small and attempt a forecast of the day to day variations of temperature. The choice lay between the five day period which the India Meteorological Department has adopted for their short period normals of temperature and the week which has been recommended by Sir Napier Shaw (4) for Agricultural Meteorology. The latter was chosen and a detailed analysis of the November and December maximum temperatures attempted with a view to forecast the temperatures in the successive weeks of December from those of the preceding weeks. The seven day periods suggested by Sir Napier Shaw, October 30 - November 5th, November 6th,—12th, etc., to December 25th– 31st, were adopted for the purpose, and they are denoted here as X_1, X_2, X_3, X_4, Y_1, Y_2, Y_3, Y_4, and Y_5. The mean weekly maximum temperature totals for the various weeks with their standard errors are set out in *Table IV*.

TABLE IV.

Period	Mean weekly Max Temp Total	S D	Period	Mean weekly Max Temp. Total	S. D.
X_1 ..	618 6	19 53	Y_1	594·8	19·08
X_2 .. .	610 8	20 62	Y_2 .	595 2	18·00
X_3 . ..	607 5	20 92	Y_3 . .	593·1	18·33
X_4 .. .	600 8	19·34	Y_4 ..	592·7	16·66
Y_1	594 8	19 08	Y_5	593·2	17·33

The departures from the means for the different weeks were then plotted for the 52 years under consideration with a view to study any apparent trend in the departures. The examination of the graph showed that there was no trend except perhaps for the values of Y_2, and it was decided to test this statistically, and so the polynomial of the fifth degree was fitted to it ([1]). The results of the analysis are given in *Table V*.

TABLE V.

Secular trend in the values of Y_2.

$$x'_2 = 18{\cdot}931$$
$$x'_3 = -4{\cdot}884$$
$$x'_4 = 7{\cdot}049$$
$$x'_5 = {\cdot}428$$
$$x'_6 = -1{\cdot}521$$

$$\text{S.D.} = 18{\cdot}7$$

Due to	D. F.	Sum of squares.	Mean square.
Polynomial fitting	5	434·4	86·88
Residual	46	16090·1	349·78
Total .	51	16524·5	324·01

The analysis shows that there is no trend in the values of Y_2, the mean square due to polynomial fitting being smaller than the mean square due to the residual.

The correlations between the different periods were then worked out and are given in *Table VI*.

TABLE VI.

Correlation coefficients between the seven day periods of November and December months.

	X_1	X_2.	X_3.	X_4.	Y_1.	Y_2.	Y_3.	Y_4.	Y_5.
X_2	·73								
X_3	·70	·65							
X_4	·48	·44	·58						
Y_1	·50	·50	·57	·70					
Y_2	·39	·41	·45	·49	·66				
Y_3	·36	·32	·52	·36	·41	·59			
Y_4	·38	·43	·48	·29	·47	·48	·42		
Y_5	·45	·40	·37	·12	·36	·55	·37	·53	

On Walkers' criteria as extended by Dr. Savur the 5 per cent. chance highest value of 'r' in a group of 36 correlations is ·45. It is found that in the above table there are 19 coefficients which exceed this value.

The highest coefficients between any November week and a December week is only ·70, which is lower than the coefficient of ·85 between the two months. Even the highest coefficient between successive weeks is lower than this figure.

The existence of the high values of the correlation coefficients indicate the possibility of forecasting the temperatures for the various periods. The forecasting of temperature for any period in this paper is based on the four periods previous to it, *e.g.*, Y_1 is forecasted from X_1, X_2, X_3, and X_4. etc.

Significance of the regression function is tested by the "z" test of Fisher by analysing the total sum of squares of deviations with 51 degrees of freedom into the two components, (i) the sum of squares due to regression with 4 D F. and (ii) the sum of squares due to the deviations from the regression function with 47 D. F., the latter serving as a basis for the random errors. "z" is half the natural log. of the ratio of the two mean squares.

The results of the analysis of variance are set out in *Table VII* below.

TABLE VII.

	Due to	D. F.	Sum of squares	Mean square.	½ log. 1/100 mean square.
For Y_1 ..	Regression . .	4	10,147 82	2,536·955	1·61678
	Deviations from regression ..	47	8,420·37	179·156	·29154
	Total .	51	18,568·19	364 078	$z=$ 1·32524
For Y_2 ..	Regression .	4	7,473 51	1,868·377	1·46384
	Deviations for regression ..	47	9,051·04	192·575	·32763
	Total .	51	16,534 55	324 010	$z=$ 1 13621
For Y_3 ..	Regression	4	7,554·33	1,888 582	1·46925
	Deviations from regression ..	47	9,578·06	203·788	·35597
	Total .	51	17,132 39	335·929	$z=$ 1·11328
For Y_4 ..	Regression	4	4,312·93	1,078·234	1·18903
	Deviations from regression ..	47	9,840 07	209·363	·36943
	Total	51	14,152·75	277·509	$z=$ 0·81060
For Y_5 ..	Regression	4	6,206·21	1,551·552	1·37091
	Deviations from regression ..	47	9,120·46	194·052	·33147
	Total ..	51	15,326·67	300·530	$z=$ 1·03944

It will be observed from the values of "z" that the mean squares ascribable to the regression function are significantly greater than the mean square of deviations from the regression function. The values of "z" obtained exceed even the 1 per cent. point.

Another way of testing the significance of the regression function is to test the significance of the values of multiple correlation coefficients. The value of the multiple correlation coefficient is obtained by the simple relation,

$$R^2 = \frac{\text{Sum of squares contributed by the regression function}}{\text{Total sum of squares of deviations.}}$$

The values of R for the five periods Y_1, Y_2, Y_3, Y_4 and Y_5 are ·739, ·672, ·664, ·552 and ·633 respectively. The significance of these values can then be tested by the tables given by Dr Wishart ([5]). The values of the multiple correlation coefficients are all significant, indicating thereby the possibility of forecasting the temperature of the different weeks of December from the preceding four weeks.

The regression equations obtained are —

(1) $Y_1 = 95 + \cdot 033\, X_1 + \cdot 143\, X_2 + \cdot 114\, X_3 + \cdot 536\, X_4$

(2) $Y_2 = 187 + \cdot 058\, X_2 + \cdot 066\, X_3 - \cdot 017\, X_4 + \cdot 542\, Y_1.$

(3) $Y_3 = 166 + \cdot 325\, X_3 - \cdot 019\, X_4 - \cdot 132\, Y_1 + \cdot 534\, Y_2$

(4) $Y_4 = 259 - \cdot 098\, X_4 + \cdot 297\, X_1 + \cdot 174\, Y_2 + \cdot 190\, Y_3.$

(5) $Y_5 = 171 - \cdot 102\, Y_1 + \cdot 442\, Y_2 - \cdot 014\, Y_3 + \cdot 385\, Y_4.$

By using the above regression equations the forecasted values of the five periods Y_1, Y_2, Y_3, Y_4 and Y_5 have been calculated. These are shown, along with the observed values, in *Plates I* and *II*.

In conclusion, I wish to express my thanks to Dr. L A Ramdas for his valuable criticisms in the preparation of this paper.

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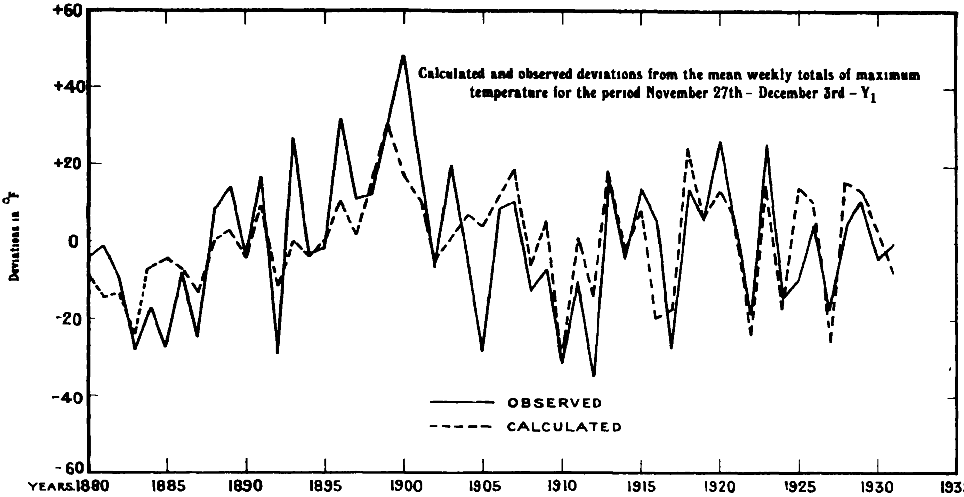
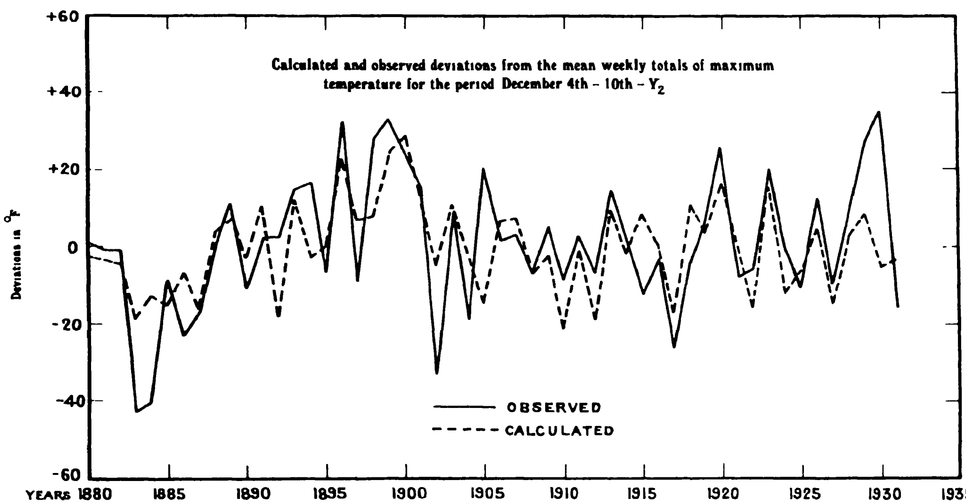
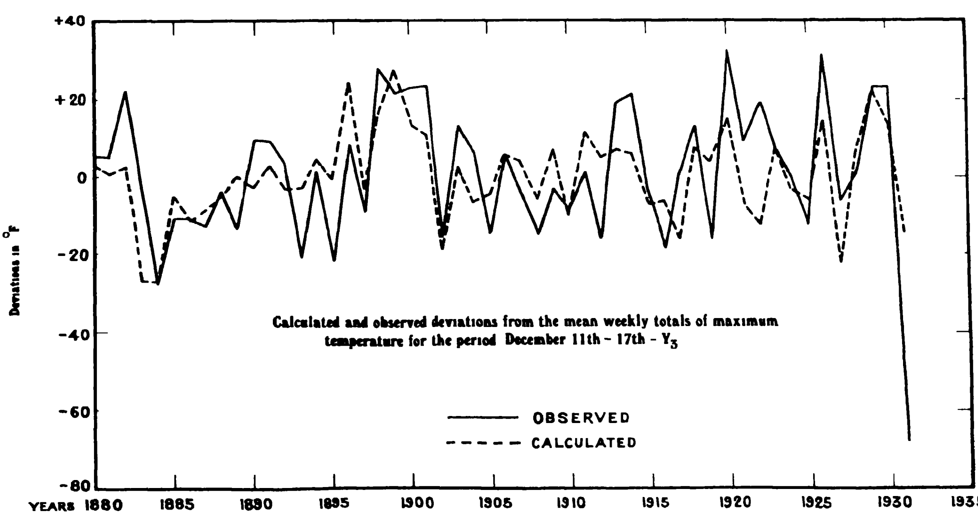
Plate No. I.







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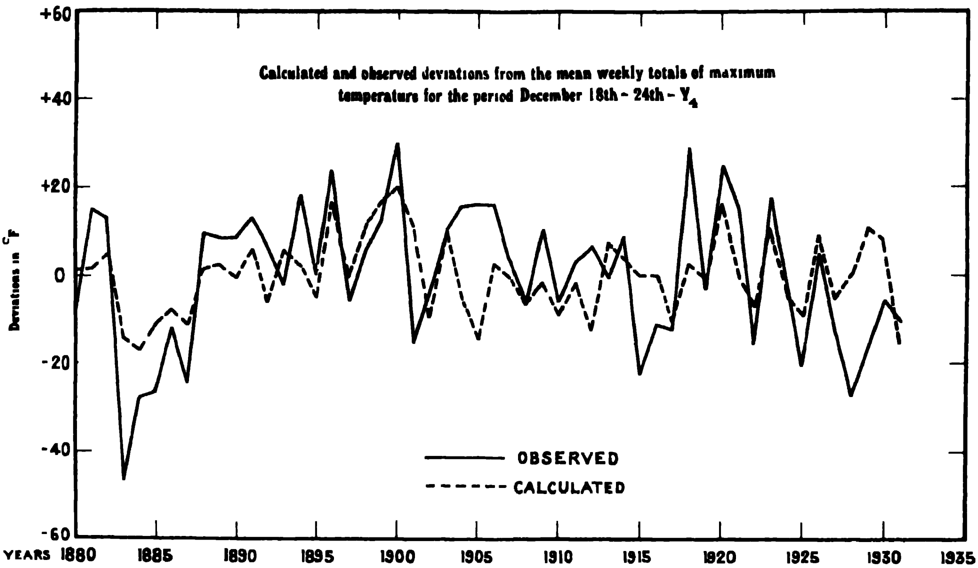

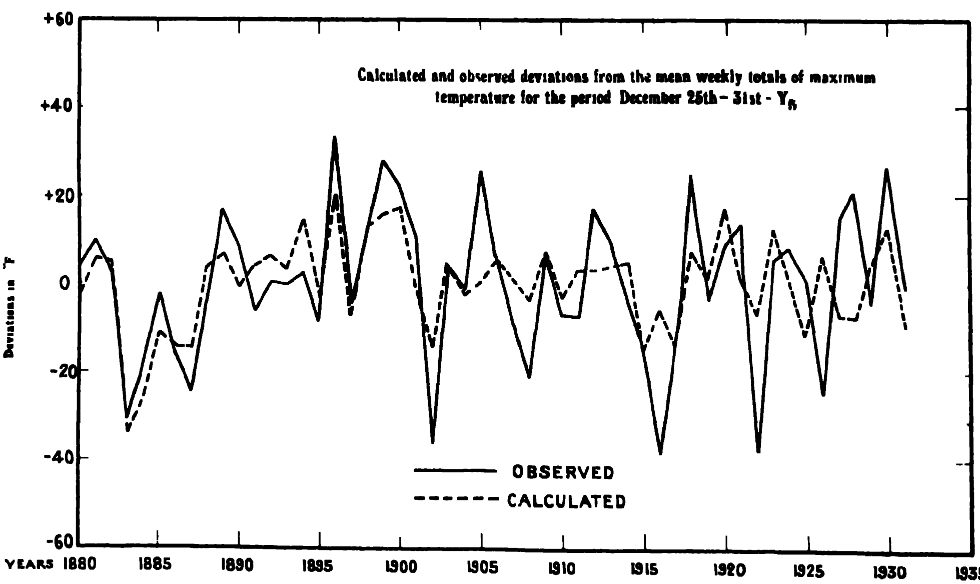

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On Forecasting Weather over Northeast Baluchistan during the Monsoon Months July and August

BY

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and

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(*Received on 13th October 1933.*)

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[See inside of back cover.

ON FORECASTING WEATHER OVER NORTHEAST BALUCHISTAN DURING THE MONSOON MONTHS JULY AND AUGUST

BY

A. K. ROY, B.A., B.Sc., and R. C. BHATTACHARYA, M.Sc.

(Received on 13th October 1933)

Summary.—The difference between barometric pressures at 0700 hrs local time at Khanpur (in the south Punjab) and Rawalpindi (in the north Punjab) is a useful factor in predicting weather over northeast Baluchistan during the two months July and August. A statistical examination of data for five years (1929-1933) confirms the belief that the days on which the pressure difference (Khanpur minus Rawalpindi) is negative are usually associated with disturbed weather, and the days with positive difference are generally fine. It is found that a forecast based on this single criterion would be correct on about 69 per cent days. The results are extremely striking when the days with large negative and positive differences are taken into consideration. It is found that out of 33 days during the above period when the difference of pressure at 0800 hrs L.M.T. on any day was 0·10 or more, rainfall was recorded during the next twenty-four hrs on as many as 29 days at one or more of the five observatories in northeast Baluchistan, while measurable rain occurred only on 1 out of 54 days associated with a positive difference amounting to 0·05 or above.

Weather over northeast Baluchistan during July and August is largely determined by the progress of depressions originating in the Bay of Bengal and travelling through central India. In the absence of an adequate weather chart extending over the whole of northern India, it is not possible for the Quetta office always to predict in good time the extension of monsoon conditions into Baluchistan. Attempts were, therefore, made to find out a method of forecast with the help of available data. A clue to such a forecast was afforded by the following.

A graph showing the day to day variation of Quetta station level pressure (at 0700 hrs local time) and maximum and minimum temperatures is prepared in the Meteorological Office, Quetta. An examination of the above graph during July and August 1933 showed that the periods during which pressure at Quetta was above normal were generally associated with unsettled weather at Quetta and *vice versa*. It was further observed that the commencement of a spell of unsettled weather at Quetta was usually accompanied with a rise of pressure above its value at 0700 hrs. on the previous day, while a fall of pressure during the last twenty-four hours generally indicated an improvement of weather at Quetta, particularly when such a fall caused the pressure to reach a value lower than the normal.

Table A giving the pressure changes in twenty four hours ending at 0700 hrs. and weather remarks and clouds in afternoons on each day during July and August 1933 bears out the above statement, especially during the second half of July and the first half of August when the monsoon was most active over northeast Baluchistan.

TABLE A.

July 1933.					August 1933.				
Date.	Pressure changes at Quetta during 24 hours ending at 0700 hrs. local time	Departure of pressure from normal, whether above or below	Weather at Quetta in afternoon and evening	Clouds at Quetta at 1700 hrs I S T	Date	Pressure changes at Quetta during 24 hours ending at 0700 hrs local time	Departure of pressure from normal whether above or below	Weather at Quetta in afternoon and evening	Clouds at Quetta at 1700 hrs I S T
1					1	- 04		K S	KN 10
2	+ 04			0	2	03	Below		KN 1
3	— 04	Below		0	3	- 02			KN 2
4 .	— 05			0	4	+ 07		T	KN 3
5	+ 01		⚡ at distance in evening	KN 1	5	+ 08	Above	T	KN 9
6	+ 09	Above		K 1	6	-- 03			KN 5
7 .	+ 03			0	7	- 12			KN 3
8 .	-- 06	Below		0	8	+ 02	Below	d	KN 10
9	— 06		..	K trace	9	+ 02			KN 8
10	+ 09			KN 1	10	+ 08		S	KN 2 CS8
11 .	+ 04		.	KN trace	11	+ 02	Above	K, r	KN 9
12 .	00			KN 2	12	+ 01		K, r	N5, AS3 CS2
13	00			KN9	13	00			KN3
14 .	— 04		.	KN3	14	13			KN trace
15	00		T	KN6 CS4	15	00	Below		KN7
16 .	00	Above	S	KN6	16	+ 06			KN6
17	+ 04		S K	KN10	17	+ 06			KN3
18	+ 01		S T, r	N10	18	03			KN2
19	— 02		T	KN 9	19	— 01			KN1
20	+ 01		T, r	N10	20	- 05			KN4
21	— 01		K, r	KN9 CS1	21	+ 07			KN1
22	+ 02		K, S	KN10	22	+ 02			KN4
23 .	— 07			KN4	23	+ 02	Above		KN5
24	— 07	Below		KN trace	24	— 03			
25 ..	— 01			KN1	25	-- 02			KN5, SK1
26 .	+ 04			KN3	26	-- 02			KN8
27	+ 06		T	KN10	27	00			KN8
28 ..	+ 04		S	sky not discernable	28	+ 02			KN trace
29 .	— 04	Above	T	KN1	29 .	— 01	Below	.	.
30 ..	— 01		.	KN4	30 .	+ 05	Above	.	KN5
31 ..	+ 01		T	KN10	31 .	+ 01		..	K1

Although the pressure changes at Quetta appeared to be of considerable help in predicting local weather during July and August, a more useful factor for the purpose of forecasting weather over northeast Baluchistan as a whole was required. Forecasters, who have weather charts for the whole of northern India to forecast from, have for long known that the movement of the trough of low pressure southwards away from the Himalayas is associated with an extension of monsoon winds up the Gangetic plain and, if this pressure change extends to the Punjab, the monsoon winds are likely to extend towards the northwest frontier, including northeast Baluchistan. This implies that weather over northeast Baluchistan during July and August is dependent upon the pressure gradient over the Punjab, being wet when pressure falls from north to south and dry when it falls from south to north. This old observation had never been subjected to statistical analysis and therefore led us to an examination of barometric pressures at 0800 hrs local time at Rawalpindi in the north Punjab) and Khanpur (in the south Punjab) on individual days during the months of July and August, during the five years 1929 to 1933. For this purpose tables were prepared showing the daily differences between pressures at the above two stations, and rainfall and weather remarks at five stations in northeast Baluchistan, *e.g.*, Quetta, Chaman, Kalat, Fort Sandeman and Harnai. A sample of these tables has been included as an Appendix.

A study of these tables confirmed the existence of a useful relationship between the difference of morning pressures at Khanpur and Rawalpindi and weather conditions over northeast Baluchistan on the same day. The results appear to be most helpful in predicting weather in northeast Baluchistan during the monsoon season, as will be evident from the *Table B* below in which the main conclusions have been summarised.

TABLE B

Khanpur pressure *minus* Rawalpindi pressure	−0·15 or more	−0·10 to −0·14	−0·05" to −0·09"	−0·01"* to −0·04"	+0·01"* to +0·04'	+0·05" or above.
Total number of days	12	21	55	74	90	54
Number and percentage of days on which weather was disturbed at one or more of the north-east Baluchistan stations	12 (100%)	18 (86%)	39 (71%)	32 (43%)	31 (34%)	2 (4%)
Number and percentage of days when measurable amount of rain was recorded at one or more of the above stations	12 (100%)	17 (81%)	33 (60%)	26 (35%)	19 (21%)	1 (2%)
Total amount of rainfall at the five stations . ..	13·5"	18·3"	17·5'	14·5"	11·9"	less than 0·1"
Rainfall per day .. .	1·13"	0·87"	0·32"	0·20"	0·13"	Nil.

*Number of days on which pressure difference was zero have been divided equally under these two columns.

It will be seen from the above table that rainfall was recorded at one or more observatories in northeast Baluchistan on 54 per cent of days associated with a negative difference between pressures at Khanpur and Rawalpindi and on as many as 87 per cent of days when the difference amounted to $-0\cdot10''$ or more. Measurable rain, on the other hand, occurred only on 11 per cent of days associated with a positive difference. Further, the chances of rain are greater, the greater the negative difference between pressures at Khanpur and Rawalpindi. Thus, rain occurred on a hundred per cent occasions when the difference was $-0\cdot15''$ or more, and only on two per cent occasions when the difference was $+0\cdot05''$ or above. Also the amount of rainfall per day is greatest when the difference is $-0\cdot15''$ or more, and decreases gradually as the negative difference becomes less, and is minimum when the difference is positive and reaches a value greater than $+0\cdot04''$.

APPENDIX.

Daily pressures (at 0800 hrs. local time) at Khanpur and Rawalpindi rainfall and weather remarks (during 24 hours ending with 0800 hrs L. M. T. the next day) at five stations in N. E. Baluchistan, 1929.

Daily pressures (at 0800 hrs local time) at Khanpur and Rawalpindi and rainfall and stations

July.	Pressures			Rainfall (in ") and Weather remarks									
Date	Khanpur	Rawalpindi	Difference	Quetta.		Harnai		Fort Sandeman		Kalat		Chaman	
	"	"	"										
1	24 40	24 42	−0 02										
2	34	28	+ 06			T			K				
3	27	38	11			2							
4 .	41	43	02			1							
5	40	45	05			2		T			K		
6	38	44	− 06										
7	36	37	− 01										
8	38	38	+ 00										
9	42	38	+ 04										
10	38	34	+ 04										
11 .	33	27	+ 06										
12	35	57	22			7		2					
13	42	47	— 05					6					
14 ..	35	49	— 14	T		4		1 8		1			
15 ..	38	38	00			T							
16 .	30	25	+ 05										
17 ..	30	39	— 09						K				.
18 ..	·37	45	— 08			2							
19 ..	46	51	— 05				.						
20 ..	48	50	— 02										
21 ..	44	45	— 01										
22 .	42	51	— 09			1							
23 ..	44	·44	00										
24 .	37	45	— 08			1		2					
25 ..	45	59	— 14			T		9	r				..
26 .	47	58	— 11	1		1	.	2 6		4		.	..
27 .	41	·57	— 16	4		T		T	.	1 1	.	·1	.
28 ..	51	·58	— 07	1 3		1 7		2		1	.	·1	.
29 ..	61	·58	+ 03	.	.		.		.	.	..	..	..
30 ..	·53	·49	+ 04	·1	..	T		..	.	4	.	..	..
31 ..	·52	·51	+ 01	..	..	..	..	6	..	..	..	..	..

weather remarks (during 24 hours ending with 0800 hrs. L. M. T the next day) at five in N. E. Baluchistan, 1929.

August	Pressures			Rainfall (in ") and Weather remarks									
Date	Khanpur	Rawalpindi	Difference	Quetta		Harnai		Fort Sandeman		Kalat		Chaman	
	"	"	"										
1	24 56	24 62	0 06										
2 ..	52	56	— 04										
3	50	48	+ 02										
4 .	47	54	— 07					2			.		
5	51	56	05			1							
6	51	47	+ 04								.		
7	47	43	+ 04										
8	45	40	+ 05										
9	51	48	+ 03										.
10	50	44	+ 06										
11	49	45	+ 04										
12	54	48	+ 06										
13	49	42	+ 07										
14	47	43	+ 04										
15	53	54	- 01										
16	57	53	+ 04										
17	56	52	+ 04										
18	50	48	+ 02										
19	52	58	- 06		ς	1		2					.
20	54	56	- 02										
21	50	63	— 13			3		4					
22	48	53	— 05			7		3				.	
23	47	47	00			T		4					
24	56	65	— 09					T	r		ς		
25	55	58	— 03			1 1		1 0					
26	50	57	— 07					2					.
27	47	62	— 15			5							..
28	63	56	+ 07										
29 ..	63	72	— 09			1					.		.
30 .	68	70	— 02	.							.	.	.
31 ..	·65	67	—·02	.	..				..	..	.	..	..

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Humidity Records obtained at Agra with Hair Elements and with Wet and Dry Elements in a Dines' Meteorograph

BY

S. P. VENKITESHWARAN.

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HUMIDITY RECORDS OBTAINED AT AGRA WITH HAIR ELEMENTS AND WITH WET AND DRY BULB ELEMENTS IN A DINES' METEOROGRAPH

BY

S. P VENKITESHWARAN

(*Received on 13th March 1933.*)

Summary—The hair humidity records obtained from the Dines' meteorograph ascents made at Agra are discussed The records obtained with a wet and dry bulb Dines' meteorograph are described, and the values of humidity obtained from this compared with the hair humidity values The paper incidentally shows also how the temperature and the hair humidity traces obtained from two meteorographs sent up with the same balloon compare

In one of the Departmental memoirs[1], while discussing the results of sounding balloon ascents at Agra during the period July 1925 to March 1928, Dr. K R Ramanathan has remarked that the humidity values obtained from the Dines' meteorograph ascents were to be considered to have only a qualitative significance Since that period numerous improvements have been made to the meteorograph by Mr G Chaterjee, Meteorologist in charge of the Upper Air Observatory, Agra, both to increase the accuracy of the pressure and temperature values, as also the humidity recorded by the hair No check or comparison has been made so far of the values obtained, and the present paper describes an attempt in this direction by means of a wet and dry bulb Dines' meteorograph

Before 1929 the humidity pen of the meteorograph was a brass strip soldered on to the invar of the temperature pen, and the hair was simply wound round a hook in the middle of this pen, and another hook in the frame of the meteorograph and there was the possibility of the tension being excessive on the hair This pen was improved by replacing it by a suitable watch spring by means of which it has been possible to have a tension of only a gramme per hair. As it is difficult to get Indian hair free from oil[2], a quantity of suitable length was obtained from one of the European hair-cutters at Poona. These hairs are kept soaked in ether just before use for at least 24 hours, and one hair is knotted into a loop, then passed through two small rings and looped again. The hair is further washed in ether and then hooked on to the frame and the humidity pen of the meteorograph. Two calibration marks, one at 0 per cent.

and the other at 100 per cent., were made by keeping the meteorograph in a glass jar containing anhydrous calcium chloride for 24 hours, and then for one hour in a jar containing water at the bottom and moist blotting paper on the sides.* When working out the humidity traces, it was assumed that the displacement of the humidity pen was proportional to the relative humidity †

The 0 per cent and the 100 per cent marks are made after completing the temperature and pressure calibrations It has been the practice to calibrate all meteorographs for temperature and pressure keeping them immersed in petrol during calibration, and one may be tempted to think that the hair must cease to be influenced by changes in the humidity, as it may be getting a coating of oil It was therefore examined whether the 0 per cent and 100 per cent. marks shifted on dipping the instrument with the hair in petrol, and it was found that the behaviour of the hair remained unchanged after being kept in petrol for some hours ‡ The behaviour of the hair also remained unchanged with time, for when the calibration marks were repeated after keeping the instruments for one week it was found that there was no shift in them It was proposed that there might be some shift in the humidity pen when the meteorograph was subjected to a change in temperature only, without change in humidity due to the relative expansion between invar and brass This was tested by examining the calibration marks obtained at the laboratory temperature and at a lower temperature near about 0° C , for the 100 per cent value at the low temperature the humidity chamber was used at about 0°C and water sprayed into it. To find out whether there was any shift in the 0 per cent value, the instruments were placed in a desiccator containing strong sulphuric acid and kept in a refrigeration chamber at about 0° C for 24 hours There was no measurable shift for a change of temperature of nearly 30°C in both the 100 per cent. and 0 per cent traces

On an examination of the humidity records obtained from the ascents made at Agra during the years 1930-32 the following conclusions were derived Almost all the records show that the hair ceases to function above heights at which the pressure is below 325 mms , (*i e* , above 9 kms where the temperature is about 250°A) for they do not show any variation of humidity above this level This has been noticed even in the records obtained from the ascents made at Agra during 1925-28[1] Out of a total number of about 160 instruments retrieved during the period 1930-32 in 51 cases humidity values either above 100 per cent or below 0 per cent were obtained Humidities were below 0 per cent in 15 cases and in two of them values below 10 per cent were recorded In 6 cases the values exceeded 110 per cent

After the introduction of Mr Chaterjee's pen release,[5] it has been possible to distinguish between the ascending and the descending traces The water freezing release has been used in all the ascents, and it is found that the pen is in most cases lifted off in the descending trace at a pressure of about 500 mms On a comparison of the humidity records during ascent and descent, it is found that the two traces are very nearly similar except that the

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*It was suggested that placing the meteorographs in a closed vessel, over $CaCl_2$ and water may not give the 0 per cent and 100 per cent marks correctly It was found that by placing the meteorographs over strong H_2SO_4 in a desiccator better 0 per cent marks could be obtained , by spraying water in the chamber instead of simply placing the instrument over water a better 100 per cent mark could be obtained

†Some experiments to test the validity of this in the case of the Dines' instrument are being undertaken

‡All the tests mentioned in this paragraph have been made using strong H_2SO_4 for 0 per cent. and by spraying water for the 100 per cent mark.

trace during descent is displaced laterally to the high pressure side by a distance equivalent to a change of pressure varying from 15 to 50 mms. An examination of the temperature record shows that in almost all the traces the temperature during the return trace is generally lower than that in the corresponding portion of the ascending trace. This is possibly due to the fact that the aneroids in the meteorograph are filled with air and that the rate of fall of the instrument is much greater than the rate of ascent, and that the air in the aneroid therefore does not attain the temperature of the outside air, and always has a lower temperature than the surrounding air and as a consequence the pen is shifted towards the high pressure side which will show itself as a lower temperature at that level. So also in the case of the humidity pen, at any point on the return trace, if the humidity remains the same but the air in the aneroid is cooler, which appears to be a fact as indicated by the temperature element, the humidity trace at this point must be displaced towards the high pressure side which is also observed from most of the traces. Since the rate of descent of the instrument is much greater than the rate of ascent, it is also possible that the hair is not able to adjust itself to the existing conditions, as much as it did during ascent and as a result, at corresponding points on the trace, if the instrument is falling from a region of higher humidity to one of lower humidity, the value in the return trace will be larger and *vice versa*. The above shows that the temperature and the humidity values during descent are not as reliable as those during ascent, and also gives us clues to distinguish between the two traces both in the temperature and humidity records.

With a view to test how the hair functioned when subjected to the variations in humidity accompanied by changes in temperature and pressure as in an actual sounding, and to test how far these values are reliable, the ordinary Dines' instrument was modified to record the wet bulb temperature also in addition to the hair humidity and dry bulb temperature. This will be an effective instrument only till the water in the wet bulb freezes, for when the water is frozen the capillary action on which the moistening depends, ceases altogether. From the soundings made with these instruments it is found that the height at which the wet bulb actually freezes is easily determined, as described in the following pages. The humidity calibration marks in these experiments were made according to the old practice, *viz.*, by using $CaCl_2$ for 0 per cent and water for 100 per cent.

The wet and dry bulb meteorograph was constructed by adding an extra temperature element in the system. *Fig. 1* shows the details of the temperature elements. The grid *A B C D* is of invar of which *A B* forms the component for the dry pen, and *C D* that for the wet pen. *E F G H* are of hard drawn brass sheet 0.010″ thick and bent into a V along its length to give it sufficient rigidity. The hinges *M*, *N* for the wet and dry pen respectively are as usual pieces of watch spring. *H* is the hair hygrometer pen fixed on to the invar piece and one end of the hair is fixed on to the small hook shown in the middle of the pen. The stirrup *K* keeps the grid rigid and also enables the grid to be fixed on to the frame of the meteorograph. It is also supported at its lower end to the frame at *S* (*Fig. 2*). One thickness of cambric was stitched on to the brass strip *GH* of the wet bulb element, two small reservoirs for water were fixed on to the meteorograph (*Fig. 2*) and a muslin thread starting from the upper reservoir was wound round the brass portion of the wet bulb element and finally dipped in the water in the lower reservoir; this served to keep this element always moist. With these instruments therefore, the wet bulb temperature, the dry bulb temperature and the humidity with the hair were recorded on the same graphited plate.* As no successful attempts had

*Some attempts were made in 1927, when two independent instruments were sent attached to the same balloon. One of them was converted to record only the wet bulb temperature, and no definite conclusions could be derived from them, as only one instrument with a fair trace was received.

been made so far to compare the accuracy of the temperature recorded by these meteorographs, one ordinary Dines' instrument and a wet and dry bulb meteorograph were sent up with the same balloon *Fig 3* (*a*) is an enlargement (about 5 times) of the record obtained with the wet and dry bulb meteorograph from an ascent made on 14th July 1932 The lowest trace is due to the dry pen, the middle one to the wet pen, and the top one due to the hair *Fig. 3* (*b*) is the trace obtained with the ordinary meteorograph with a "double temperature"[4] element which was sent up along with the above instrument.

The values of humidity obtained from the hair as also the wet and dry bulb temperatures for three ascents are given below. In *Tables I* (*a*) and *I* (*b*) values of temperatures and humidities obtained from an ordinary Dines' meteorograph and a wet and dry bulb meteorograph which were sent together are tabulated *Table* I (*c*) gives the values obtained with a wet and dry bulb meteorograph sent alone.

TABLE I (a).

(*Ascent on 13th July 1932*)

Pressure in mms.	Dry bulb temperature				Wet bulb temperature	Humidity % from hair				Humidity % from Wet and Dry bulb
	Wet and dry bulb instrument I.		Ordinary Dines' instrument II			Wet and dry bulb instrument.		Ordinary Dines' instrument		
	Ascending	Descending	Ascending	Descending		Ascending	Descending	Ascending	Descending	
700	305·5		306·7	.		51		53	.	..
650	300·3	.	300·4		295·0	58		62		64
600	293·2	..	293·7		291·5	75		81		86
550	288·3	.	288·6	.	286·5	90		93		84
500	284·6	.	284·4	.	282·1	83	..	88	82	76
450	280·2	..	279·7		277·0	81	75	80	85	68
400	275·0	..	274·7	274·1	272·7	78	63	73	83	73
350	269·6	..	269·7	268·4	266·5	74	58	68	72	54

TABLE I (b)

(*Ascent on 11th July 1932.*)

Pressure in mms	Dry bulb temperature: Wet and dry bulb instrument, Ascending	Dry bulb temperature: Wet and dry bulb instrument, Descending	Dry bulb temperature: Ordinary Dines' instrument *, Ascending	Dry bulb temperature: Ordinary Dines' instrument *, Descending	Wet bulb temperature	Humidity % from hair: Wet and dry bulb instrument, Ascending	Humidity % from hair: Wet and dry bulb instrument, Descending	Humidity % from hair: Ordinary Dines' instrument, Ascending	Humidity % from hair: Ordinary Dines' instrument, Descending	Humidity % from Wet and Dry bulb
700	305.8		305.4	303.9		52		63	66	
650	299.5		299.5	298.3	294.6	50		73	75	66
600	293.2		293.5	292.5	291.3	78	74	90		85
550	288.0		288.1	287.6	287.3	95	97	101	94	94
500	284.3	283.0	293.5	283.3	283.8	94	80	99	102	96
450	280.8	277.9	281.2	280.5	278.8	82	86	88	74	81
400	274.8	272.7	275.3	274.9	273.5	77	74	91	81	84
350	270.4	267.0	271.0	268.7	268.0	55		72	75	69

* The pen release has not functioned here, it has been assumed that the temperature is less during descent than that during ascent

TABLE I (c)

(*Ascent on 9th May 1932.*)

Pressure in mms	Dry bulb temperature: Ascending	Dry bulb temperature: Descending	Wet bulb temperature	Humidity from hair: Ascending	Humidity from hair: Descending	Humidity from Wet and Dry bulb.
700	306.0		291.8	25		25
650	300.5		287.7	25		25
600	294.5		284.0	28		30
550	287.0	285.5	280.0	33		41
500	280.3	279.0	275.3	45	59	49
450	274.2	274.0	269.7	57	60	45

The instruments in all cases had a rate of ascent greater than 3 metres per second[5] and the values of humidity were calculated from the wet and dry bulb temperatures in the ascending trace. These values have been corrected for pressure.

It was found in all the records obtained that there was a sharp kink as at *A* (*Fig.* 3*a*, *Fig.* 3*c* shows *A* much enlarged) on the ascending trace of the wet bulb record due to the sudden freezing of the water on the wet bulb element.* The wet and dry bulb temperatures at which the water froze as also the temperature attained by the wet bulb just after the solidification of the water, are given below for a few instruments

TABLE II

Instrument No	Date	Dry bulb temp when water freezes	Wet bulb temp just before freezing of water	Wet bulb temp just after freezing of water
76/30	13th July 1932	−3·2°C	−6·5°C	0·5°C
156/30	14th July 1932	−2·6°C	−5·0°C	0·5°C
190/30	9th May 1932	−0·8°C	−7·0°C	0·2°C
27/27	18th October 1927	0°C	−5·3°C	2·0°C

From the nature of the kink it appears that the formation of the ice was not gradual but sudden. On the other hand the return trace shows in some of the instruments the effect of the melting process and the two traces separate out, showing even at first sight an abnormally lower wet bulb temperature than can be reasonably expected. In calculating the humidity, values of wet bulb were picked from the ascending trace only up to the freezing point.

Tables I (*a*), I (*b*) and I (*c*) show fair agreement between the values of humidity obtained from the hair during ascent and from the wet and dry bulb elements, and the difference between the humidity values as obtained from the hair and the wet and dry bulb temperatures have exceeded 10 per cent only in 5 cases. But the tables show that the humidities obtained from the hair are sometimes uniformly higher than those calculated from the wet and dry bulb values which must be the result of the 100 per cent and 0 per cent calibration marks made with water and $CaCl_2$ being not accurate. Calcium Chloride being not a good dehydrating agent, and 100 per cent humidity being not attained by simply keeping the instrument over water in a closed space, the value of the humidity per unit displacement of the hair is slightly greater than that in an ideal case.

Figs. 3 (*a*) and 3 (*b*) show the humidity traces obtained from two separate hairs in independent instruments but sent up together, and it is found from these that the hair humidity records resemble each other very well in their form, and that the hair is fairly sensitive to the changes met with in the atmosphere during the ascent.

*This sharp kink was visible on scrutiny in the instrument retrieved in 1927, where the temperature element of an ordinary Dines' meteorograph was converted into wet bulb, and the temperatures at the kink are given in the last row in Table II. The accuracy of the temperature with these meteorographs is only of the order of about 2° to 3°C, the aneroid and the temperature element have since been improved very much by Mr. Chaterjee.

On comparing the values of dry bulb temperatures during ascent recorded by two instruments sent up together it is found that they agree within ½°C except for occasional differences of the order of 1°C But the difference between the ascending and descending traces is very large due to the reasons already mentioned

I am thankful to Mr G Chaterjee for all his valuable help in the preparation of this short note

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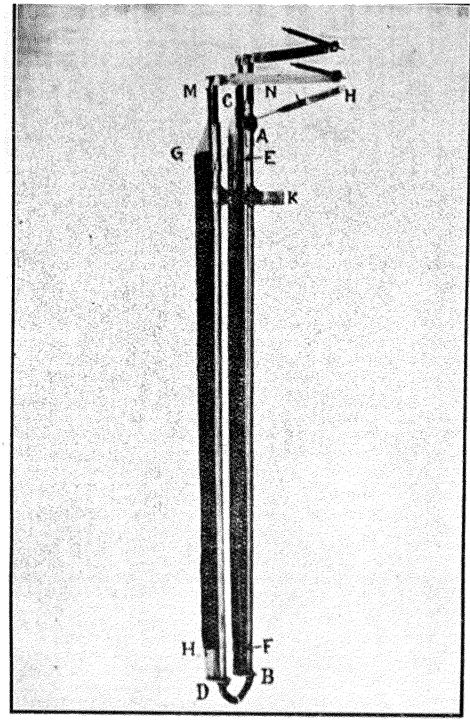

Fig. 1.

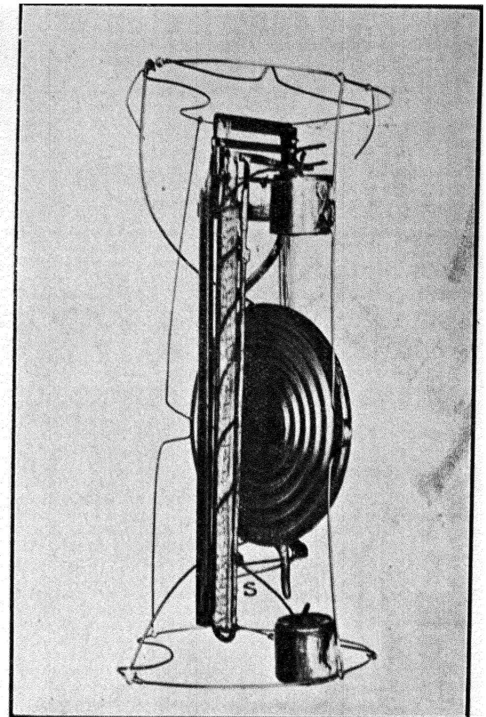

Fig. 2.

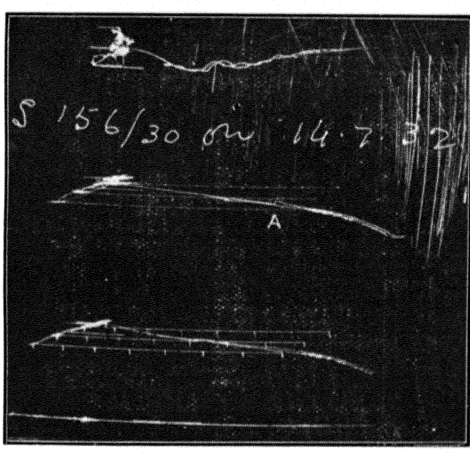

Fig. 3a.

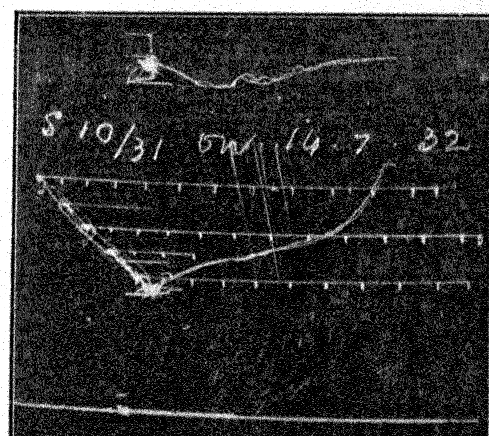

Fig. 3b.

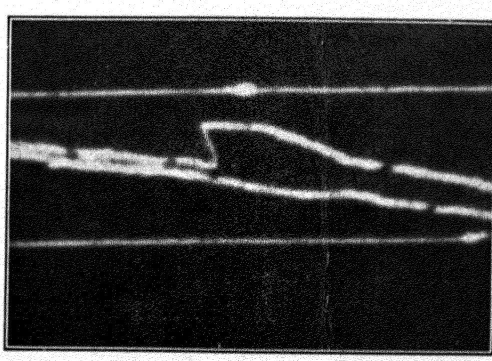

Fig. 3c.

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A Preliminary Study of a Tornado at Peshawar

BY

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A PRELIMINARY STUDY OF A TORNADO AT PESHAWAR

BY

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(*Received on 17th June 1933.*)

1. **Introduction**—On the 5th April 1933, a tornado was observed near the western boundary of Peshawar Cantonment. This phenomenon has never been recorded before at Peshawar and is practically unknown in north-west India although pendant-shaped extensions of cumulo-nimbus cloud have been seen occasionally in the plains of the Punjab and N. W. F P The tornado was of moderate intensity and passed mostly over open, uncultivated country. Comparatively little damage was caused and no loss of life occurred. *Fig. 1* is a rough sketch of the locality over which the tornado passed and its track has been indicated by a dotted line The commencement of the track was found in the Kajuri Plain to the south of Peshawar and it terminated in the vicinity of Islamia College to the west of Peshawar. *Plates I to VII* are photographs of the tornado taken at the request of the author by Leading-aircraftsman Russel Pleasants of the Photographic Section of No. 20 (A. C.) Squadron, R. A F., Peshawar. The plates were exposed at approximately five-minute intervals from 11-55 hrs. to 12-25 hrs. and clearly show the growth and decay of the tornado. It was not possible to take photographs of the tornado-cloud before it reached the ground owing to delay in obtaining a clear field of view. From *Fig. 1* it will be seen that the phenomenon passed unpleasantly close to the aerodrome and the cantonment. All machines were put into the hangars and a warning was telephoned to Islamia College of the approach of the tornado In the following paragraphs the meteorological conditions before, during, and after the tornado are described as fully as possible, and the probable cause of the phenomenon is discussed in para. 5. There is little doubt, that, like the "twisters" of the American prairies, the Peshawar tornado was caused by vigorous convection combined with the interaction of different air-masses. (NOTE.—All times given in this paper are *local time, i.e.,* 43 minutes behind Indian Standard Time).

2. **Conditions preceding the tornado.**—On the 4th April, a depression which had remained practically stationary over Baluchistan moved in a north-easterly direction into the N. W. F. P. The chart (see *Fig. 3*) for the 4th April based on 08-00 hrs. observations shows a low-pressure area over Baluchistan flanked by a wedge of high pressure penetrating into south-west Punjab. With the approach of the depression pressure fell rapidly at Peshawar, the barometer

reading (corrected for temperature) being 0·3" (*i.e.*, 10 mbs.) less at 19 hrs. than at 10 hrs. Of this large fall of pressure, about 23% may be accounted for by diurnal variation, but the remaining 77% was evidently due to the vigorous ascent of warm damp air. *Fig. 10* shows a section of the weekly barograph trace for the 4th, 5th, and 6th April. The sky remained mainly overcast with low and medium cumuliform cloud during the morning and afternoon of the 4th, except for occasional bright intervals in the forenoon. Considerable cumulo-nimbus cloud developed over the surrounding hills in the afternoon, and thundershowers occurred in the evening and at night The surface winds swung round the compass from north to south several times during the day, finally becoming north-north-easterly in the morning of the 5th April The upper winds over northwest India in the morning and evening of the 4th are shown in *Figs 6a* and *6b* It will be seen that with the movement of the deepening depression into Waziristan the southerly current over Quetta and Peshawar strengthened considerably. Upper air temperatures taken by the R A F at Risalpur (30 miles east of and 150 ft lower than Peshawar which is 1,150 ft above sea-level) on the 4th, 5th, and 6th April are given graphically in *Fig. 12a* and the relevant tephigrams are shown in *Fig 12b.* The lapse-rate on the 4th up to 8,000 ft. was from 2° to 3° per 1,000 ft increasing to 4° and 5° per 1,000 ft between 8,000 ft and 15,000 ft Unfortunately the wet bulb thermometer of the strut psychrometer was unserviceable, and consequently humidity data are not available. But, judging from local conditions and from the observations made at neighbouring hill stations, the air on the 4th up to 15,000 ft was at least half-saturated

The chart based on observations at 08-00 hrs on the 5th April is shown in *Fig. 4.* It will be seen that the wedge of high pressure over the N W F. P. had completely disappeared and had been replaced by a well-marked depression with a moderate gradient, its centre being situated south-southwest of Peshawar Temperature had fallen well below normal in Baluchistan, and slightly below in N W. F P. and southwest Punjab, but had risen above normal in north and east Punjab Although the actual temperatures at 08-00 hrs did not indicate any sharp discontinuity at the surface, *Fig 9*, giving the departures of the mean temperature from normal, reveals a fairly steep gradient from west to east with a " front " passing through Peshawar and extending roughly from north to south over the N W F P and Punjab and curving to southwest over Sind The surface winds indicate a flow of air across the isobars roughly towards the centre of the " low " with a line of convergence extending from north to east Punjab. (It should be noted in connection with the south-south-east wind shown at Cherat, a few miles east of Peshawar, that Cherat is a hill-station about 3,500 ft. higher than Peshawar). The upper winds at Karachi, Quetta, Peshawar, Lahore and Agra, are represented in *Fig 7a* and the height-line, velocity curve, and trajectory for Peshawar are shown in *Fig 13.* A " cold " front had obviously passed Quetta on the night of the 4th in view of the northwesterly direction of the upper winds and subnormal temperature on the morning of the 5th. Its approximate position at 08-00 hrs on the 5th April over the N. W. F. P. was presumably near and parallel to that of the zero line in *Fig. 9.* In this connection it should be noted that at Peshawar on the morning of the 5th there was an abrupt change of wind direction at 0·8 km. from northeast to south. The lower current may be associated with the circulation of the preceding high-pressure system and probably originated from the eastern Himalayas, but the upper current formed part of the " warm " sector of the advancing depression and had travelled from the Arabian Sea.

Upper air temperatures taken by the R. A. F. at Risalpur on the morning of the 5th are given in *Fig. 12a*. Up to 6,000 ft. the readings were slightly higher than

on the 4th, but appreciably lower from 7,000 ft. to 15,000 ft. The pilot reported marked " bumpiness " from 2,000 ft. to 14,000 ft.—particularly between 5,000 ft. and 7,000 ft. From 4,000 ft. to 14,000 ft. he was almost continuously in cloud. It will be observed that the air was almost isothermal up to 3,000 ft.—with a lapse rate of 1° per 1,000 ft., but from 3,000 ft upwards the decrease of temperature with height was almost steady at 4° per 1,000 ft In view of the very moist state of the air this lapse rate was greater than the saturation adiabatic (see *Fig 12b*) At Peshawar on the 5th the sky was heavily covered at first with all the main types of cloud, the most predominant being cumulus over the hills, strato-cumulus (estimated height about 3,000 ft.) and alto-cumulus, the direction of movement in each case being between south-southwest and south-southeast. The sky cleared a little overhead in the forenoon and there were short, sunny intervals, but cumulus and cumulo-nimbus cloud developed and increased rapidly especially over and near the adjacent hills. (Peshawar is situated in a horse-shoe shaped plain with mountains all round except for a gap to the east southeast, the foothills to the west being within 10 miles of the observatory) At midday the sky was heavily covered with towering cumulo-nimbus clouds, the bases being at a level height estimated to be about 2,500 ft. and the tops extending to varying heights of more than 10,000 ft A light shower accompanied by thunder and hail stones occurred at 11-42—11-17 hrs. and was followed within a few minutes by the appearance of a writhing funnel-shaped cloud extending downwards in a southwesterly direction from a dense black mass of cumulo-nimbus cloud. The progress of the various meteorological elements, as indicated by the recording instruments is shown in *Fig 11* The surface winds which had previously been light northerly, veered to east-southeast at 10-20 hrs and to south-south-west at 10-45 hrs The velocity then increased to 15—20 m. p h and the direction fluctuated between south and southeast At the moment the thundershower occurred the winds were 15—25 m p h from southeast Temperature rose slowly from 62·5° F at 08-00 hrs. to 71 at 10-45 hrs and then sharply to 73·5° at 11-15 hrs subsequently falling to 72° at the time the tornado began, similarly the wet-bulb temperature rose to 64° at 11-15 hrs. and fell to 61·5° at 11-50 hrs It will be seen that the barograph indicated a continuous rise of pressure to 11-20 hrs and then showed a very slight fall. Percentage humidity which had been decreasing steadily during the morning became irregular after 10-15 hrs with sudden rises and falls (see *Fig 11*)

3. Conditions during tornado – The funnel cloud, which was first observed at 11-52 hrs tapered downwards and rotated anti-clockwise round its axis as seen from the ground It swung to and fro a little and, after rising and descending, it finally reached the ground at 11-55 hrs. about 5 miles away from the observatory When it touched the earth a mass of mud and debris shot up all round the base of the funnel, see *Plates II–V* The whirling column then rapidly thickened and the edges became darker The development of the tornado will be clearly seen from the photographs. The whole column was observed to proceed approximately towards the northeast. At first, the base appeared to move more quickly than the top, causing the column to become curved, but later the top seemed to accelerate and the column became attenuated The counter-clockwise vertical ascensional movement was clearly visible, and the uprush into the cloud base seemed to be amazingly rapid. At times an optical illusion was caused and the condensed water vapour appeared to be circulating downwards inside and upwards outside the funnel, the centre of which seemed to be clear and hollow. The tornado passed close to the aerodrome and machines were hastily put away into the hangars. Although no sound was heard at the observatory, eye-witnesses near to the phenomenon heard a loud roaring noise " like a railway train ". *Plate IV* was taken at 12-10 hrs. when the tornado was near to the meteorological office. It was then at its most active stage and had developed a peculiar shape at its base, similar to that of an arrow-head. The

height of the top was estimated to be between 1,500 ft. and 2,000 ft. At 12-15 hrs. the whirling column became much thinner and at 12-20 hrs. it developed a " kink ", and, although seemingly making an effect to recover, the column finally degenerated into a very thin, bent and twisted line which broke in two, and eventually disappeared at 12-27 hrs. A subsequent investigation of the district over which the tornado passed revealed that comparatively little damage had been caused, a large part of the track being over barren and stony ground Moreover, the rate of travel was so slow—estimated to be about 10 m. p. h. or less—that it was fairly easy to avoid. A few kutcha buildings were destroyed at the villages of Achini and Spina Warai (see *Fig. 1*). A number of small trees were uprooted, and larger trees were stripped of their foliage and covered with mud. An uneven furrow about 90 ft. wide and 1 ft. deep was ploughed up for a distance of nearly $1\frac{1}{4}$ miles over open, uncultivated country. At Spina Warai two tethered calves were lifted bodily and thrown to the ground unconscious, and a man working in the fields was stripped of his clothing. A number of birds were killed. Otherwise there was no loss of life. It is estimated that approximately two acres of crops were uprooted or destroyed. It appears that damage was caused not so much by surface winds or explosive action, as by the violent uprush of air in the central vortex. Reports were received that the tornado was preceded by a brief hailstorm Large stones fell between Spina Warai and the road to Jamrud According to Professor Strover of Islamia College they were elliptical, or nearly " stream-lined " in shape, the length of the axes being from $1\frac{1}{2}''$ to $1\frac{3}{4}''$ by $\frac{3}{4}''$ to $1\frac{1}{4}''$. It is interesting to note that, looking from southwest to northeast, the tornado funnel was situated on the right-hand side of the main cumulo-nimbus tower and the rain and hail fell mostly on the left-hand side of the track The length of the path of the tornado was approximately $4\frac{1}{2}$ miles, the spot where the funnel cloud first touched the ground being in the Kajuri Plain west of Sarband village and near the Besai spur (2,515 ft high). The track was very clearly visible over bare soil but less defined over land under cultivation Unfortunately the " twister " did not pass sufficiently close to the observatory at Peshawar to affect the instruments to any great extent (see *Fig. 11*). At the commencement of the tornado the surface wind was between southeast and south from 15 to 20 m p h. At 12-15 hrs, shortly before the phenomenon died out, the wind veered round to west and finally became northerly at the time the tornado disappeared. Pressure fell very slightly from 11-50 to 12-05 hrs and then rose a little but the microbarograph record showed no sudden change Temperature fell about one degree from 11-50 to 12-15 hrs. and then dropped 1·5° fairly rapidly, rising again at 12-30 hrs The humidity rose suddenly from 55% at 11-55 hrs to 65% at 12-15 hrs. and then dropped to 60% at 12-30 hrs. The wet-bulb rose very slightly (about 1°) from 11-50 to 12-30 hrs.

4. Conditions after the tornado.— The sky continued mainly overcast in the early afternoon with cumuliform and nimbus cloud There were further thundershowers with occasional hail. The sun broke through at 15 00 hrs. and cloud decreased rapidly in the evening. The sky cleared completely at night. The surface winds were moderate and gusty from north-northwest to north-northeast in the early afternoon but strengthened and backed to northwest later Between 13-20—13-30 hrs. there was a lull and the wind swung round the whole compass Evening upper winds over northwest India on the 5th are shown in *Fig. 7b*. It will be noted that the northeasterly wind of the morning at Peshawar had been replaced by a north-northwesterly wind up to 1 km. At $1\frac{1}{2}$ kms. the wind was easterly, with a deep, strong southerly current above from 2 kms. to 4 kms. Evidently the relatively " cold " air from the northwest had undercut the " warm " southerly air to a depth of nearly 5,000 ft. between the time of the tornado to the time of the evening pilot-balloon ascent, *i.e.*, from 12-30 hrs. to 16-00 hrs. Except for a slight rise of 2° just after the tornado, and a rise of 5° from 15-00— 16-15 hrs. when the sun shone through a

break in the clouds, temperature fell continuously the rest of the day. It will be noticed from *Fig 11* that a sharp fall occurred both in the dry and wet bulb temperatures at 13-30 hrs. On the 6th the weather was fine all day with a little cirrus and cirrostratus in the sky and patches of cumulus and cumulo-nimbus over the hills. Upper air temperatures taken at Risalpur (see *Fig. 12*) showed a marked drop up to 11,000 ft. and the upper winds at Peshawar had resumed their normal direction from northwest to west (see *Fig 8*). The general indications were that the depression had filled up considerably and had moved into the eastern Himalayas (see *Fig. 5*).

5. Discussion as to the cause of the tornado—Before proceeding to discuss in detail the mechanism of this tornado, it should be pointed out that the morning weather charts in India are, of necessity, based on observations made at 08-00 hrs. *local* time and are therefore not synoptic. Also, in view of the fact that most of the observations in the vicinity of Peshawar are at hill-stations of varying height it is almost impossible, with such unstable conditions, to draw a complete and detailed picture of the meteorological elements for any given height The very presence of the hills and the lack of observations to the west of Peshawar (*i.e.*, from Afghanistan) add to the difficulties of arriving at definite conclusions regarding any local meteorological phenomena However, an attempt has been made, in spite of the complexities of the situation, to arrive at an explanation of the phenomenon. The two main factors contributing to the formation of the tornado appear to have been :—

(*a*) an updraught caused by active convection at the level at which the funnel-cloud began—possibly assisted by local vertical currents due to uneven heating of the ground, and

(*b*) the interaction of air masses from different sources and of different directions producing vorticity in the ascending current.

It should be noted first of all that the depression was in the process of filling up, as indicated by the rise of pressure since the early hours of the 5th (see *Fig 10*), and that it was proceeding in approximately a northeasterly direction. Moreover, the centre of the low pressure system was gradually moving towards Peshawar. There were evidently three air masses involved in the formation of the phenomenon, namely —

(*i*) A " warm " and relatively moist, unstable, mass of air from south-southwest, with its source of origin in the north Arabian Sea or Persian Gulf The wind velocity in this mass was from 20 to 25 m p h. at 1,000 ft increasing to 35 to 40 m p h. at 10,000 ft

(*ii*) A " cool " and drier air mass from northeast brought in from the south-east by the preceding " high ". This air probably originated in the eastern Himalayas, but must have travelled over a fairly long path above the plains of east Punjab As a result of this journey and also in consequence of its descent to lower level this air had become stratified and warmed appreciably The velocity of this current at 1,000 ft. was about 15 m. p. h.

(*iii*) A " cold " air mass approaching from between north and northwest with its origin in the mountainous region of northeast Afghanistan or even further north The wind velocity in this air at 1,000 ft. was from 15 to 20 m p. h.

At the time of the 08-00 hrs. chart on the 5th it would appear that at Peshawar the air from the south was overrunning the air from the northeast along an " active up-glide " surface of separation. Owing to the northeasterly movement of the depression the " warm " air mass was advancing to and the " cool " air mass

retreating from Peshawar. That the surface of separation between these two currents extended down to the ground (or very close thereto) between Peshawar and Lahore is indicated by the surface winds. A dotted line in *Fig. 4* marks the probable position of the " front ". It will be noted that the line passes through a slight dip to the south in the isobars Owing to the warming of the northeasterly current, the surface temperatures do not reveal a well defined line of discontinuity. An examination of the upper air temperatures at Risalpur on the 5th, however, shows a sudden change in the lapse-rate at 3,000 ft. (1·22 kms. m. s. l.) which is approximately the same height (1·15 kms. m. s. l.) of the discontinuity in wind direction above Peshawar—the difference probably being due to the greater angle of slope of the surface of separation at Risalpur. Incidentally, the pilot, being in the habit of taking readings at every 1,000 ft. above ground level, probably failed to detect an inversion between 2,000 ft and 3,000 ft Owing to the lack of observations from Afghanistan and Waziristan it is not possible to ascertain an exact dividing line between the " cold " air from the northwest and the " warm " southerly air. But the existence of a " passive up-glide " surface to the west of Peshawar on the morning of the 5th may be assumed from its appearance later in the day. A " front " is certainly indicated to the east of Quetta, and the upper winds at this station (see *Fig. 7a*) confirm that the " cold " northwesterly air had become fully established there The *estimated* position of this " front " has been entered in *Fig. 14* by a double dotted line. If sufficient data were available it might be possible to draw a third " front " showing a line of demarcation between the cold northwesterly current and the warmer northeasterly current However, it would appear from the trajectory of the evening pilot-balloon ascent on the 5th that the northwesterly current had undercut both the northeasterly and the southerly current Hence the third " front " probably existed, although ill-defined, as a joint extension of the other two in some westerly or northwesterly direction The interaction of the three air currents at 08 hrs on the morning of the 5th is shown diagrammatically in *Fig. 4a* (see also *Fig. 7a*), and the estimated relative position at this time of the air masses in the vicinity of Peshawar is given in *Fig. 11b* In the latter the angles of slope of the surfaces of separation have purposely been exaggerated (A rough calculation based on the estimated distance of the " front " from Peshawar and the height of the northeasterly current gives an angle of slope of approximately 1 : 100). The advancing cold air from the northwest has been drawn with a " nose " in front to show retardation at ground-level Such retardation generally occurs with an inrushing and undercutting northwesterly current—especially in such mountainous surroundings as Peshawar For simplification the three air masses will be referred to from now on as " warm ", " cool " and " cold "

If a reference now be made to *Fig. 11* it will be seen that just before 11 hrs. the surface wind had become southerly It may be presumed therefore that with the movement of the depression the " cool " air mass had receded a little beyond Peshawar and had been replaced at the surface by a narrow tongue of " warm " air. It will be noted that with the change of wind direction the temperature rose a few degrees. Actually the humidity fell slightly but the lower layers of the " warm " current had probably become relatively dry owing to the passage of the air across the Sind Desert and the arid plains of southwest Punjab Meanwhile, the " cold " air had approached nearer to Peshawar and the situation became favourable for the creation of a vortex. As suggested by Wegener (1) there is a tendency for a vortex with a horizontal axis to be formed at the nose of the wedge when a cold front is advancing with a pronounced overhang, *i e*, a squall-line in mid-air In this case, however, the presence of an " active up-glide " surface of separation between the " warm " and the " cool " air mass is also important inasmuch as it probably facilitated the creation of a vortex with a more or less vertical axis. That vigorous convection was taking place was

evident from the formation of towering cumulo-nimbus cloud (see photographs) and from the fall of hail preceding the hailstorm. As already mentioned in paragraph 2, the lapse-rate of temperature in the " warm " air was super-adiabatic indicating that an active upward evacuation was taking place. Again, an examination of the height-line of the pilot-balloon ascent on the morning of the 5th (see *Fig. 13a*) gives a mean rate of ascent of 3·2 kms. in 15 minutes, *i.e.*, 700 ft. per minute whereas the balloon was filled to rise at 550 ft. per minute. Hence there was a mean vertical wind of 2 m. p. h. Also, if the points at $7\frac{1}{2}$ and $8\frac{1}{2}$ minutes on the height-line are regarded as correct then there must have been a vertical wind of nearly 20 m. p. h. between 4,250 ft. and 6,550 ft. In this connection, it will be noted that the pilot at Risalpur reported excessive bumpiness between 5,000 ft. and 7,000 ft. There had been an occasional burst of sunshine earlier in the morning, and probably even in the " cool " air there was slight local convection owing to uneven heating of the ground. In any case, the advance of the " cold " wedge from the northwest must undoubtedly have enhanced the evacuation and upward movement of the " warm " air. Thus we have a vortical movement formed at the nose of the " cold front " combined with central vertical convection within the " warm " air mass which had become sandwiched between the " cool " and " cold " air masses. The upward motion of the " warm " air was sufficiently strong to cause condensation below the proper level of the cloud and in this way the initial development of the funnel cloud took place ([2]). A glance at the photographs is sufficient to convince one that this is what was actually taking place as a black mass of condensed water-vapour is visible at the top of the tornado beneath the main base of the cumulo-nimbus cloud. It is evident that the up-draught of " warm " air was not exactly vertical but towards the northeast. Hence the extension downwards of the funnel cloud in a south-westerly direction. As explained by Humphreys ([3, 4]), the heat liberated by the condensation would increase the convection and therefore the spin. The drag from above would cause an extension of the vortex to lower levels until it finally reached the ground. Sufficient moisture being available, the reduction of pressure within the core due to the balancing of centrifugal force would cause adiabatic cooling of the air and consequent condensation. In this way, the whirl became visible as an upward spiralling mass of water drops. Its development is clearly shown in the photographs. *Plate I* shows the tornado just after touching the ground with its axis presumably parallel to the surface of separation between the " cool " and " warm " air masses. *Plate II* illustrates the intensification of the phenomenon due to increased convection. With the narrowing of the gap between the " cold " air and the " cool " air the lower part of the column became straightened—as will be seen from *Plates III* and *IV*. As one would expect, the tornado travelled with the " warm " air in approximately a northeasterly direction, *i.e.*, parallel to the direction of the depression itself. At the same time, however, the nose of the cold wedge was advancing more rapidly than the " cold " air at the ground and was gradually overtaking the retreating " cool " air. Moreover, the " cool " air had apparently curved round the tongue of " warm " air and penetrated as a northerly current below the nose of the cold wedge causing a secondary " cold front " at the surface. The combination of these two effects may explain the curvature of the funnel cloud as shown in *Plates V* and *VI*. With the gradual lifting of the " warm " air from the ground, the tornado started to decay. Convection became less vigorous. The spin was therefore retarded and pressure increased inside the column. As a result some of the rotating water-vapour evaporated and the column became less opaque. Finally, the attenuated column was cut in two—probably by the nose of the advancing cold wedge penetrating the surface of separation between the " warm " and " cool " air. Thus the dynamical wall, already weakened, round the distorted and elongated tube of water-vapour, collapsed. There was a rapid adjustment of

pressure in the two halves of the broken column, which quickly disappeared—the rotation becoming dissipated in eddy turbulence. Referring to *Fig. 11*, it will be noted that during the progress of the tornado the surface winds veered to west and then to north, becoming north-northeasterly after the phenomenon had disappeared. The microbarogram shows a slight fall (·01″) and then a slight rise (·02″). It would therefore appear that when the tornado touched the ground there was a convergence of air towards the low pressure at the centre of the column causing an incurved spiralling of the surface winds. The " cold " air did not replace the " cool " air at ground-level until 13-30 hrs and was preceded by a small secondary whirl, or eddy, as indicated by the change of wind direction through 360° (see *Fig. 11*). That a change of mass took place at 13-30 hrs is borne out by the sudden drop of temperature and the simultaneous fall of the wet-bulb together with an increase of wind velocity. The development of nimbus cloud and the frequent occurrence of thunder storms with hail in the afternoon showed that the " warm " air was still being forced upwards by the advancing " cold " air. The evening upper winds at Peshawar on the 5th (see *Fig 13b*) indicate that the " warm " air had been lifted to a height of about 5,000 ft By the following morning the northwesterly current was completely established at Peshawar (see *Fig 8*), and the depression had moved away.

6. Conclusion.—The object of the author in the preceding paragraphs has been to explain the cause of the tornado in a simple manner along the lines used by Giblett in his paper on line-squalls (5). Only a preliminary note has been attempted as a complete discussion would necessitate the use of vortex equations. It is hoped, however, to carry out a detailed comparison of the Peshawar tornado with tornadoes which have occurred in Bengal (6), the United States, and other countries with a view to arriving at a mathematical as well as a physical interpretation of this phenomenon In the opinion of the author, an essential part was played by the " cool " air in the formation of the tornado under discussion inasmuch as it facilitated the development of a vortex with a vertical axis The part played by the cold wedge was that of creating vorticity at its snout The reason for the rare occurrence of a " twister " at Peshawar is that the depressions which pass across northwest India in the cold weather do not usually bring about such a suitable juxtaposition of air masses as occurred on this occasion, although the formation of mid-air cold fronts are quite common. Also the air in the " warm " sector of these depressions is normally not so unstable as it was in this case No reports have been received of the appearance of a tornado elsewhere in northwest India on 5th April although thunderstorms occurred at many stations To facilitate reference to the various places mentioned in this note a key-map is given in *Fig 2*

Finally, the author wishes to thank Mr R L Dixit, B Sc , for his assistance in the preparation of the diagrams and also Dr A K Das, D Sc , for some helpful criticisms.

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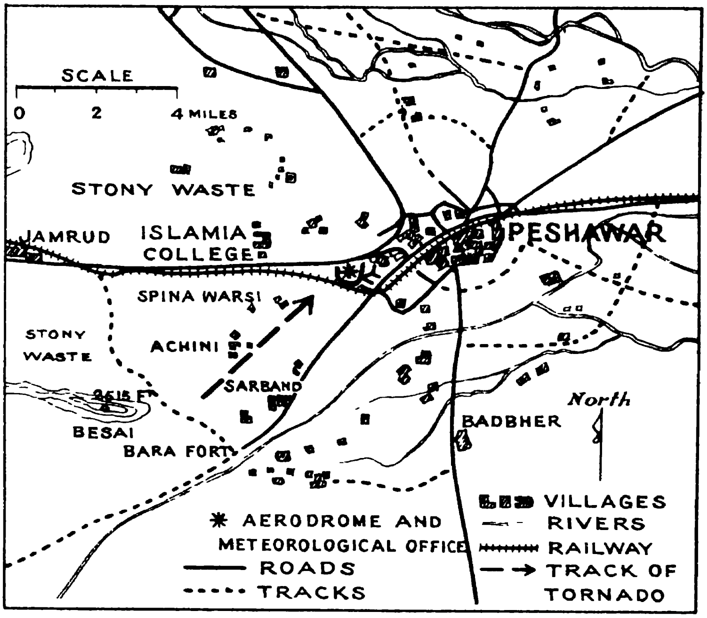


FIG 1

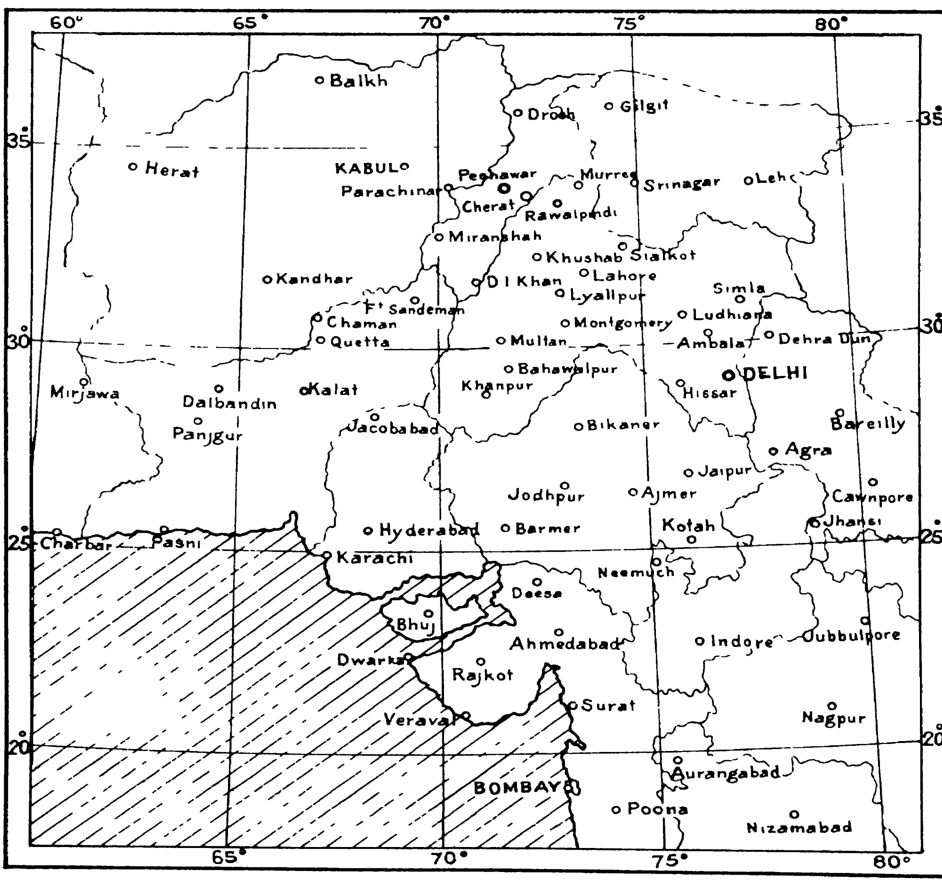


FIG 2

Govt Photozinco Office Poona, 1933.

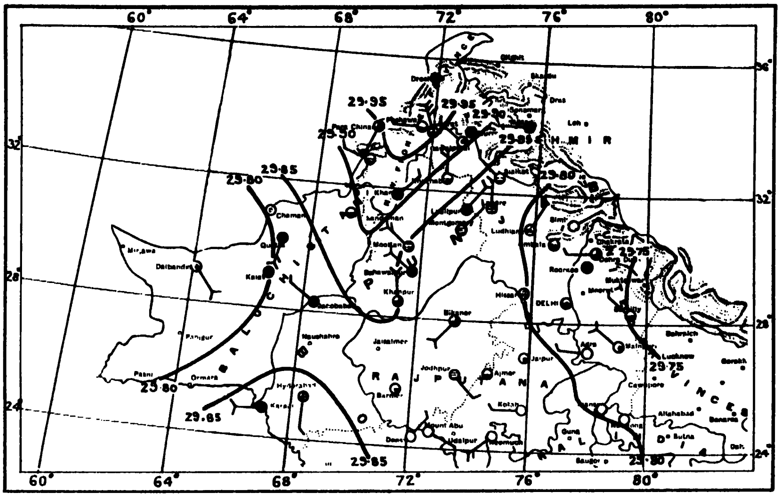


Fig. 3. April 4th 1933. At 8 Hrs. (L.M.T)

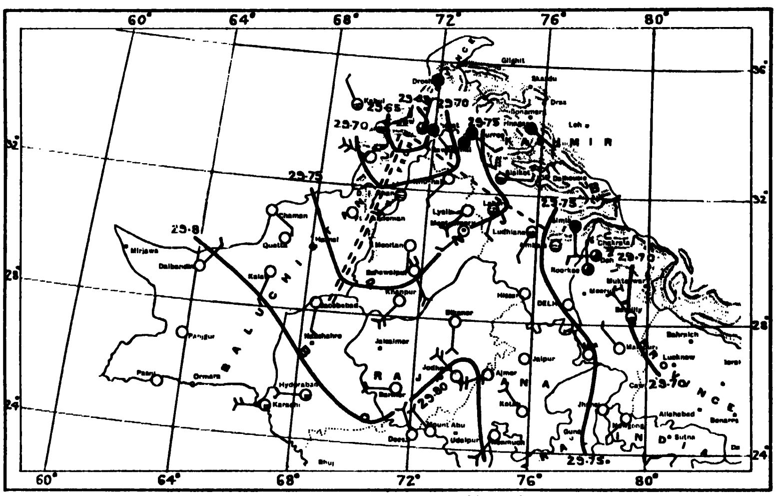


Fig. 4. April 5th 1933. At 8 Hrs. (L.M.T.)

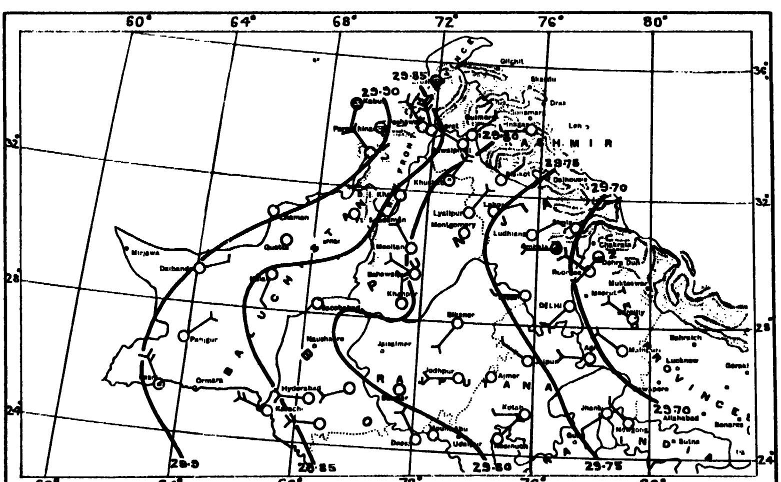


Fig. 5. April 6th 1933. At 8 Hrs. (L.M.T.)

Govt. Photozinco Office Poona, 1934.

MORNING UPPER WINDS

EVENING UPPER WINDS

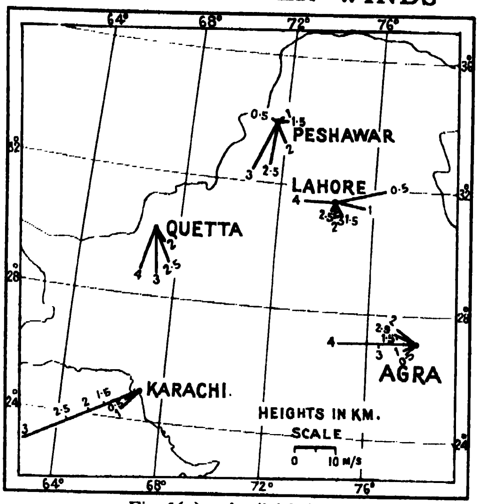


Fig. 6(a). April 4th 1933.

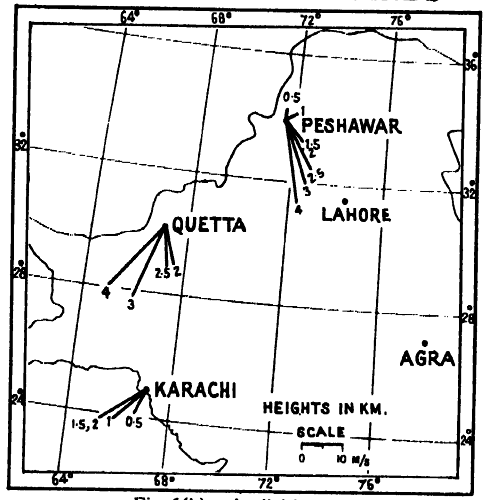


Fig. 6(b). April 4th 1933.

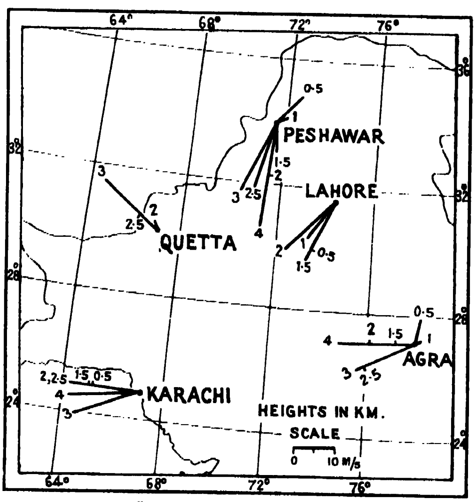


Fig. 7(a). April 5th 1933.

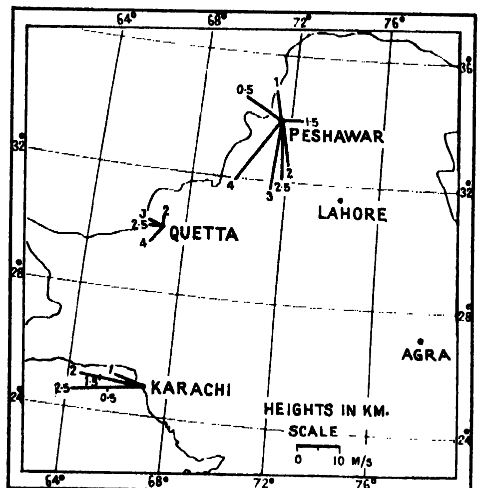


Fig. 7(b). April 5th 1933.

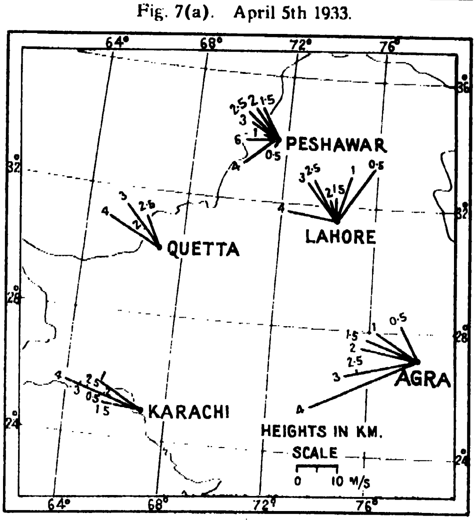


Fig. 8(a). April 6th 1933.

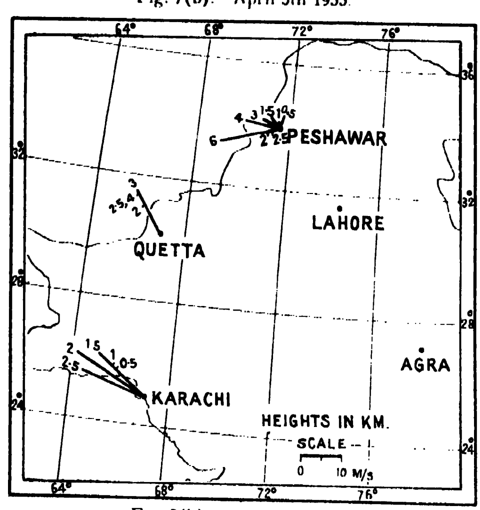


Fig. 8(b). April 6th 1933.

Govt. Photozinco Office Poona, 1933.

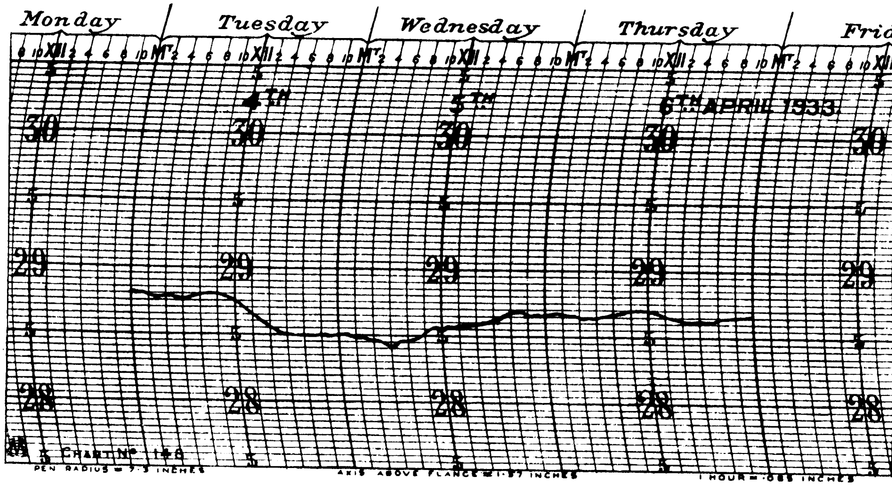
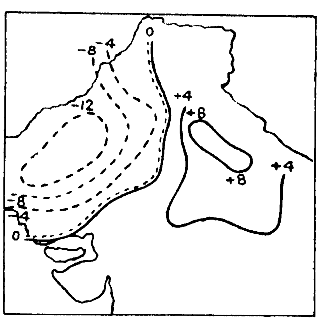


Fig. 10. Barograph Record at Peshawar



DEPARTURE OF MEAN TEMPERATURE OF DAY FROM NORMAL.

Fig. 9. April 5th 1933.

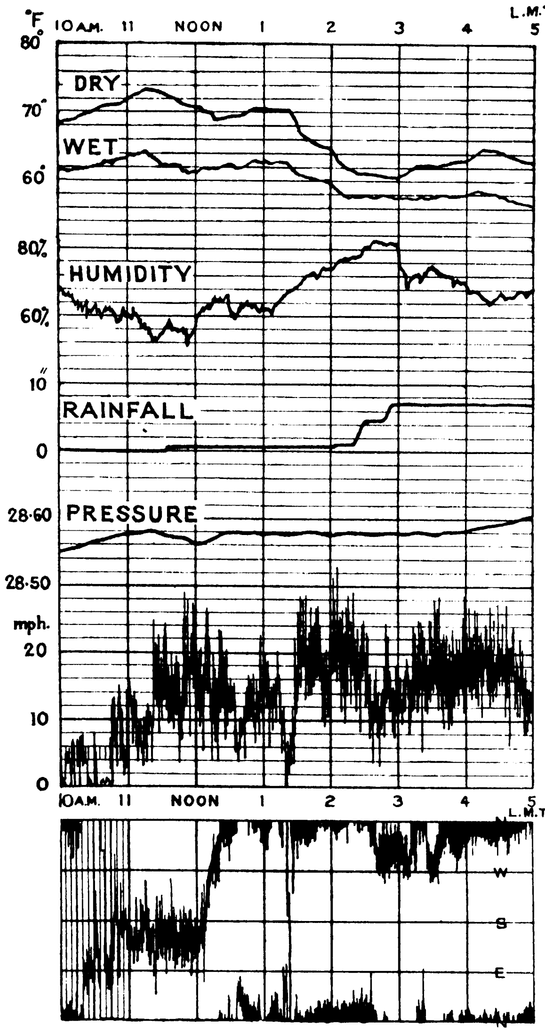


Fig. 11. Peshawar April 5th 193 .

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UPPER AIR TEMPERATURES AT RISALPUR

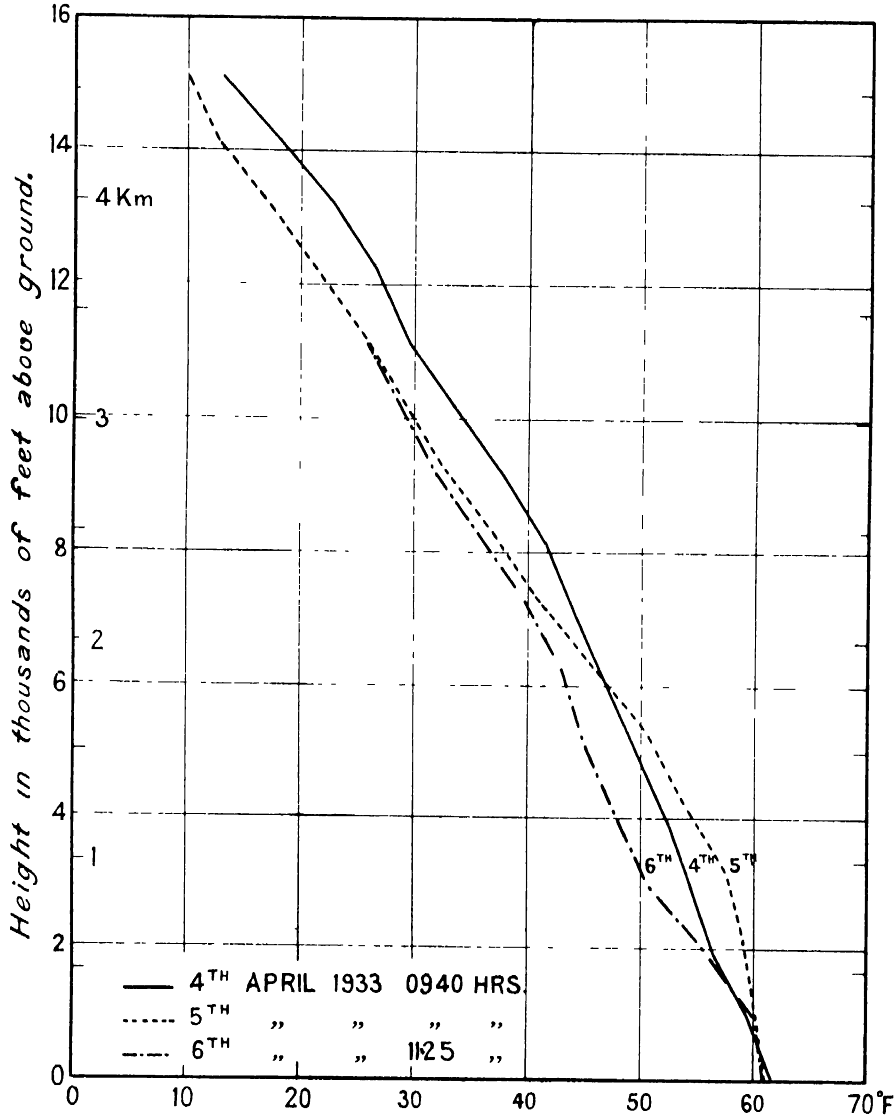
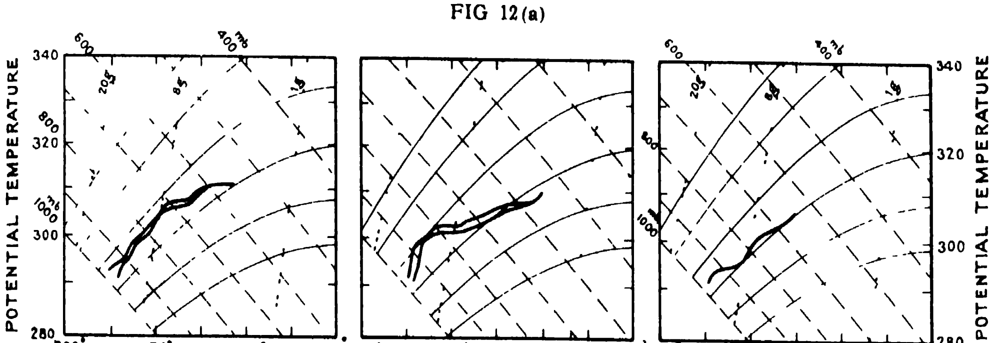


FIG 12(a)



April 4th 1933 (09 40 hrs) April 5th 1933 (09 40 hrs) April 6th 1933 (11 25 hrs)

FIG 12(b)

Govt Photozinco Office Poona, 1933

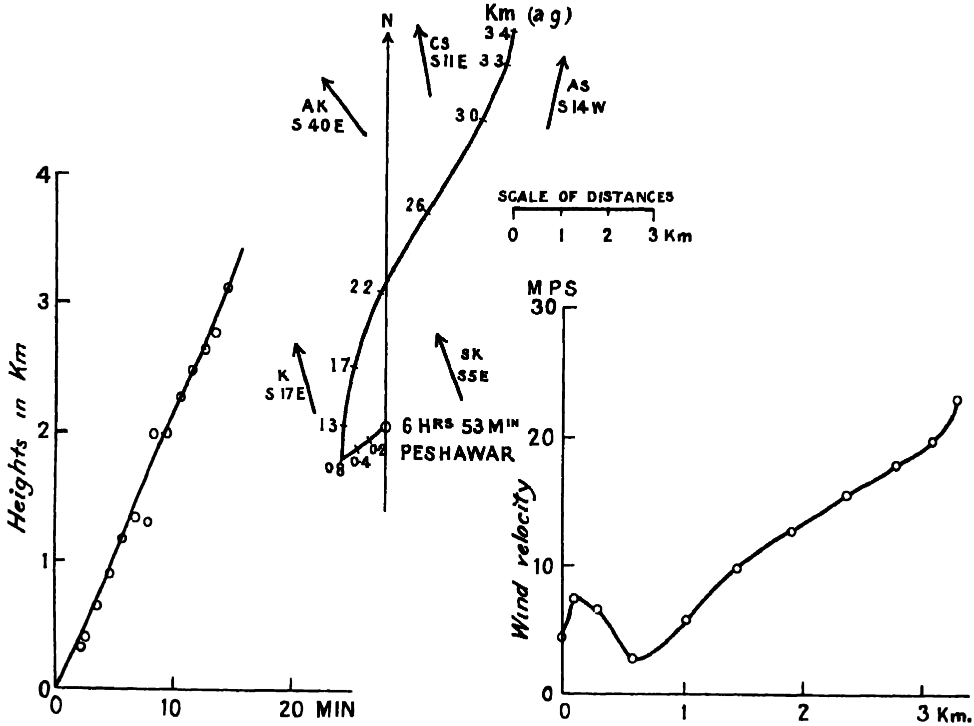


FIG 13 (a)

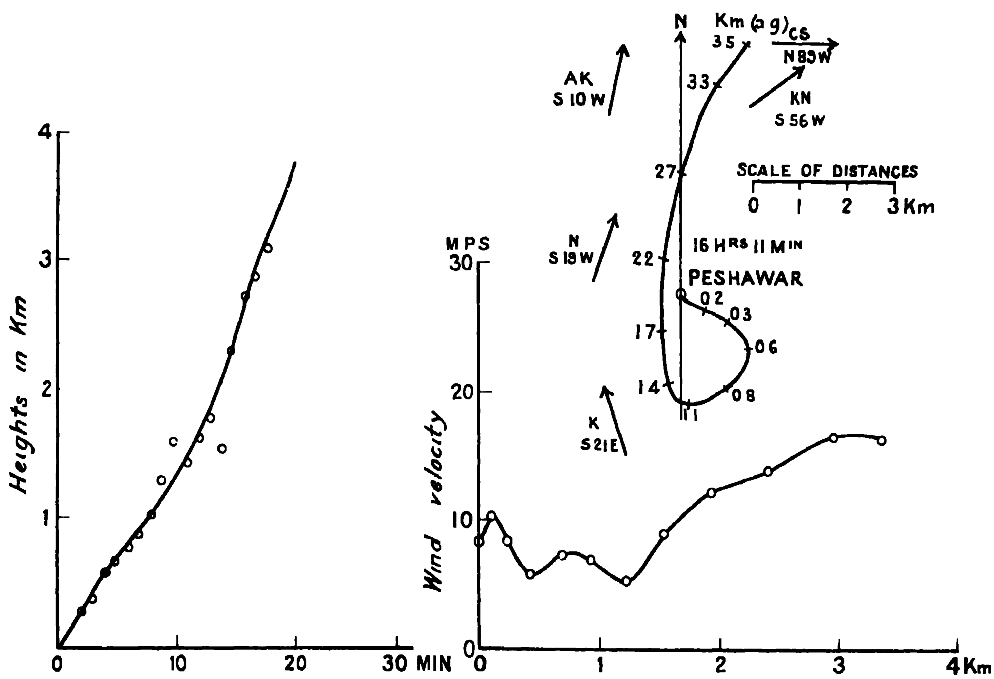
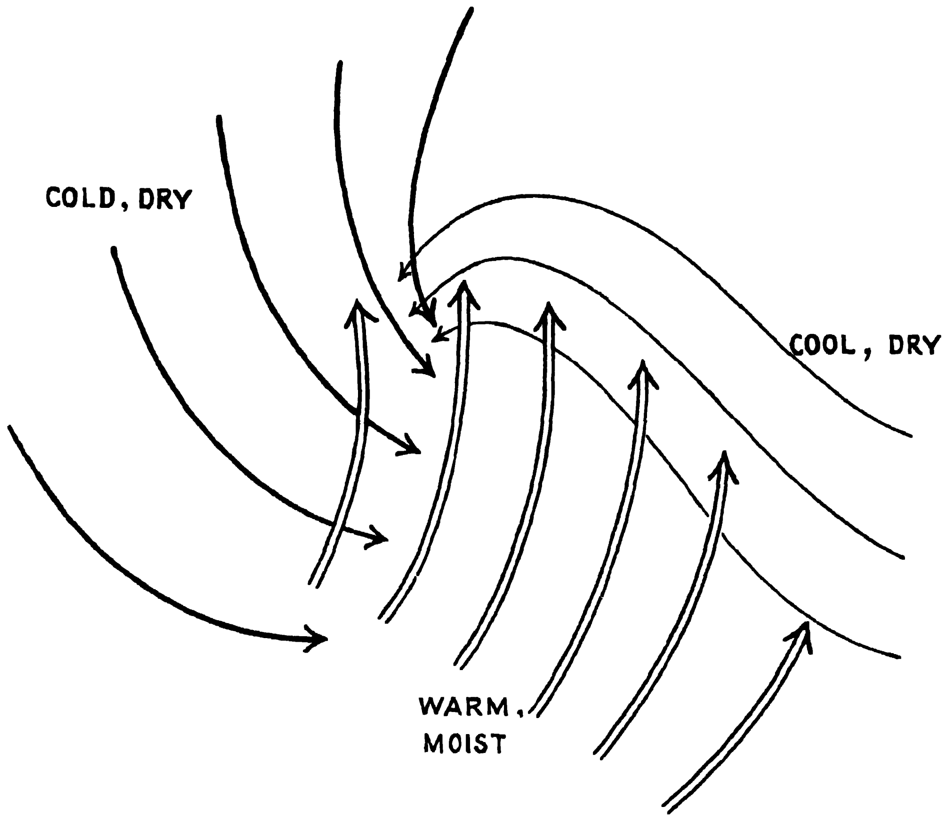


FIG 13 (b)

PILOT BALLOON TRAJECTORIES WITH HEIGHT LINES AND VELOCITY CURVES ON APRIL 5th 1933

Govt Photozinco Office Poona, 1933



Warm air from S SW, moist and unstable.
Cool air from NE SE, relatively dry and stable
Cold air from NNW WNW, fresh, dry and stable

FIG 14th(a) APRIL 1933 at 8 Hrs (L M T)

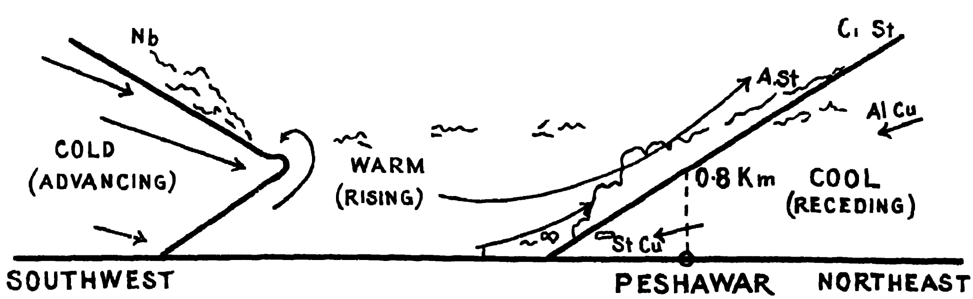


Fig. 14(b) Vertical section through Peshawar at 8 Hrs (L M T) in direction in which depression was moving

Govt Photozinco Office Poona 1933

PLATE I.

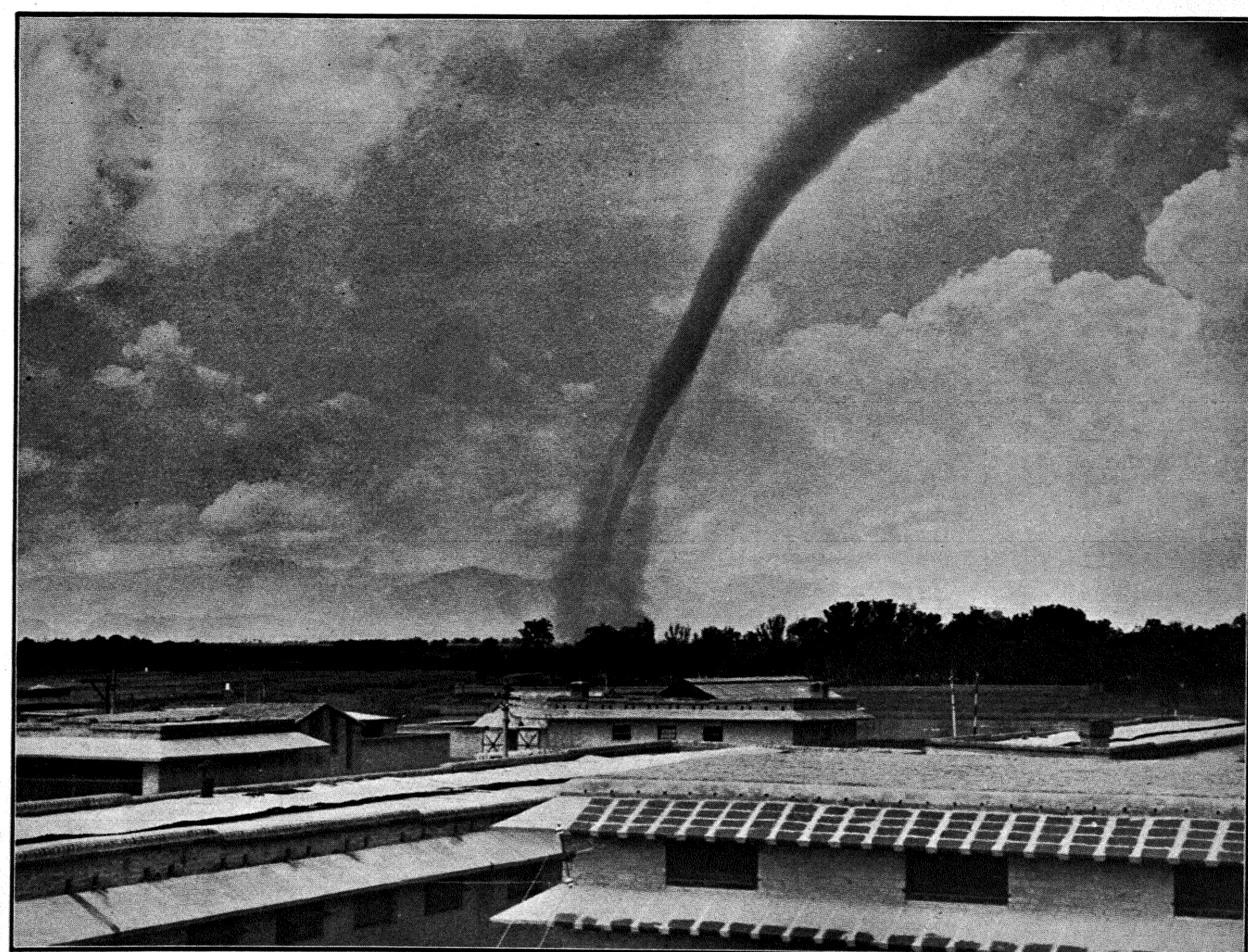
G. P. Z. P. 1933.

Tornado at Peshawar on April 5th 1933 at 11-55 Hrs. (L. M. T.)

PLATE II.

G. P. Z. P. 1933.

PLATE III.



G. P. Z. P. 1933.

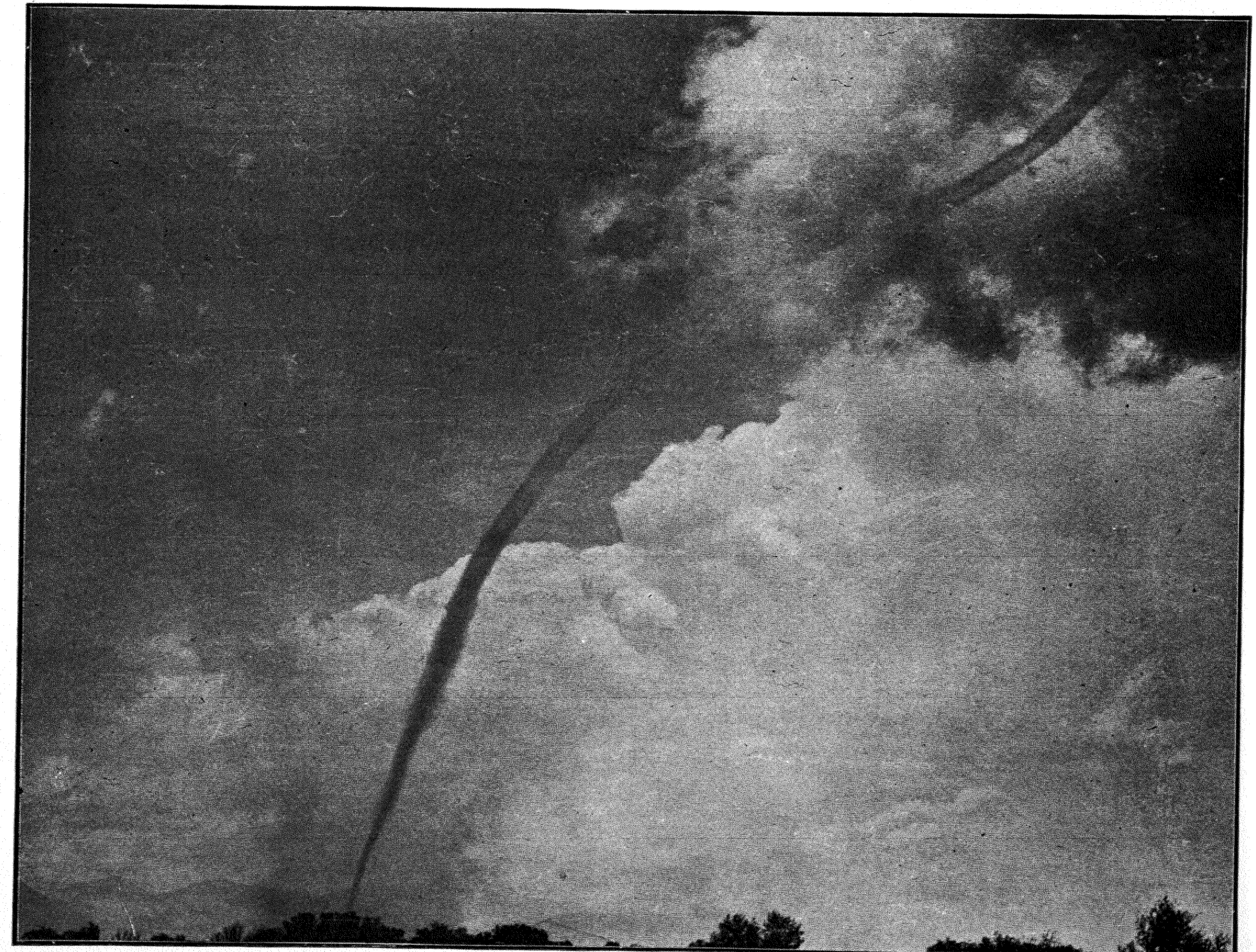
12-05 Hrs. (L. M. T.)

PLATE IV.

12-10 Hrs. (L. M. T.)

G. P. Z. P. 1933.

PLATE V.



G. P. Z. P. 1933.

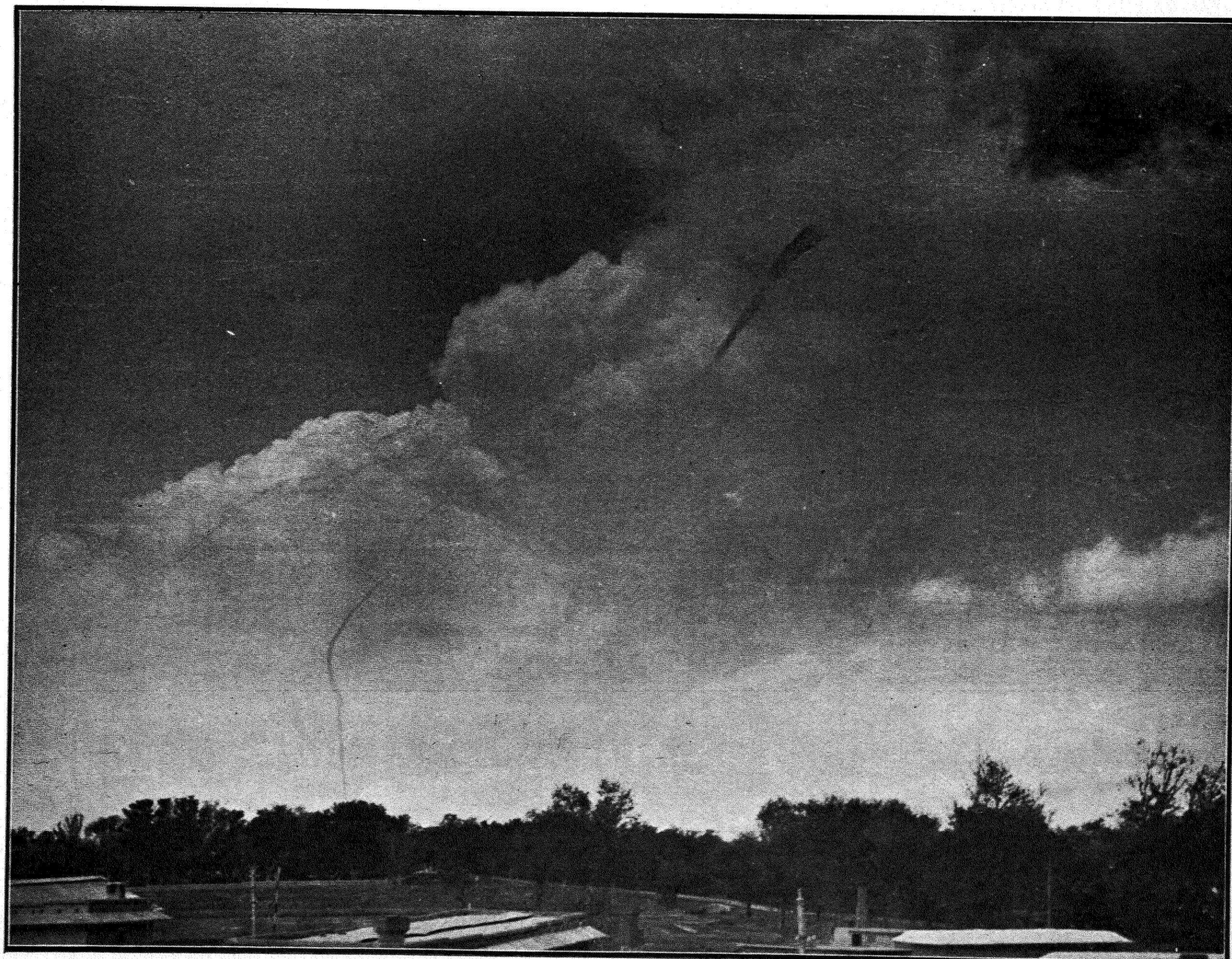
12-15 Hrs. (L. M. T.)

PLATE VI.

G. P. Z. P. 1933.

12-20 Hrs. (L. M. T.)

PLATE VII.



G. P. Z. P. 1933.

12-25 Hrs. (L. M. T.)

INDIA

METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. V, No. 55.

On the Nature of the Frequency Distribution of Precipitation in India during the Monsoon Months, June to September

BY

D. SANKARANARAYANAN.

(*Received on 9th February 1933.*)

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ON THE NATURE OF THE FREQUENCY DISTRIBUTION OF PRECIPITATION IN INDIA DURING THE MONSOON MONTHS, JUNE TO SEPTEMBER

BY

D. SANKARANARAYANAN.

(Received on 9th February 1933)

Abstract—June to September rainfall of 68 representative Indian stations situated in the field of the monsoon current is analysed with a view to test the nature of the frequency distribution $\sqrt{\beta_1}$ and β_2, according to the Pearsonian notation, are obtained for these stations and the variations in their magnitudes traced The departures of these constants from 0 and 3 are tested for their significance The paper concludes with the remark that the departures are not sufficiently high to lead to the assumption of a non-normal distribution over the greater part of the plains of India

1 The forecast formulæ developed by Sir Gilbert Walker ([1]) for foreshadowing the monsoon rains of India have been in use in this department for the last 25 years Recently an attempt has been made to calculate the chance of success of these forecasts on the definite assumption of a normal distribution for the calculated values of the rainfall amounts An examination of the nature of the distribution seemed, therefore, profitable Such an examination is attempted in this paper

2 Grouping the divisions of India into homogeneous blocks as regards rainfall, for the purposes of forecasting, could, it is believed, be facilitated if one understands the nature of the frequency distribution in each division The guiding principle at present is the pooling together of those adjacent divisions which either bear a high inter-correlation or have similar high correlations with the forecasting factors It is suggested that this may be supplemented by the examination of the magnitudes of the frequency constants

3 In this connection it may be interesting to note that Sir Gilbert Walker ([2]) has made, to quote his own words, a " preliminary attempt " to understand the variations of the annual rainfall of India But this was mainly to see how far India is liable to drought as compared with other countries In this paper, however, rainfall during the monsoon season only (June-September) has been considered, as the main forecasts are issued for this season , further, over most of India the major part of the precipitation occurs during this period The analysis of the frequency distributions has been made by the method of curve fitting developed by Karl Pearson ([3]) and tests have been applied to see how far the deviations of these distributions from the " normal " type can be considered significant

4. For this purpose, 68 stations, distributed in the field of the monsoon current, representative of the various orographical features of the country and having a

record of at least 60 years, were selected. These are shown in *Plate I* along with the number of years' record available for each station. The full records for each station have been utilised in the present investigation.

5. The stations selected may be arranged into three groups according to the total seasonal rainfall (*i*) those with an average monsoon rainfall of over 200″, (*ii*) those with falls between 200″ and 20″ and (*iii*) those having less than 20″. Only one station, Cherrapunji, falls in group one, 52 in group two and 15 in group three; of the 52 stations in group two, only seven have more than 100″. The departures from normal in group (*i*) were classified under intervals of 6″, those for (*ii*) in 2″ intervals, while a 1″ interval was used for group (*iii*). There are only 6 stations whose class intervals exceed $\frac{1}{4}$ the standard deviation and in a few cases the classification has been too fine ([1]) Uniformity in the length of the class intervals, was attempted in order to make the frequency tables comparable A departure falling on a boundary line between two intervals was counted half in each of the two intervals Sheppard's correction for grouping was also applied. In a great majority of cases the frequencies appeared to satisfy the following conditions laid down by Professor Karl Pearson (*vide* Draper's Company Research Memoirs—Biometric Series II) as desirable before one can successfully attempt fitting curves

I. The frequency starts from zero, increases to a maximum and then falls again to zero.

II There is generally contact of the frequency curve at the extremities of the range.

6. The frequency constants $\beta_1=\frac{\mu_3^2}{\mu_2^3}$ and $\beta_2=\frac{\mu_4}{\mu_2^2}$ (μ_2, μ_3 and μ_4 being the 2nd, 3rd and 4th moments) were worked out for each station It has been shown by R A. Fisher ([5]) that for tests for departures from normality $\sqrt{\beta_1}$ and β_2 are good criteria Hence these quantities were calculated and are given in *Tables I* to *IX*, and also in *Plate II*

7. A glance at the tables will show that the values of $\sqrt{\beta_1}$ and β_2 deviate very much from those for the "normal curve, *i e* from 0 and 3 respectively. We have now to see how far these variations may be considered to be significant A symmetry is measured by $\sqrt{\beta_1}$ the root being given the same sign as μ_3 It has been shown by Egon S. Pearson ([6]) that for samples of N from a normal population, $\sqrt{\beta_1}$ has a standard error of $\sqrt{\frac{6}{N}\left(1-\frac{3}{N}+\frac{6}{N^2}-\frac{15}{N^3}+\quad\ldots\right)}$ and the distribution is nearly normal. The magnitude of $\sqrt{\beta_1}$ forms therefore an excellent test for departures from normality As for β_2, its distribution is skew and has a standard error of $\sqrt{\frac{24}{N}\left(1-\frac{15}{2N}+\frac{27}{8N^2}-\frac{2319}{16N^3}+\cdot\ \cdot\ \cdot\ \cdot\ \cdot\right)}$ If we wish to examine the significance of β_2, we are faced with a real difficulty caused by the paucity in the number of years of data The sampling series for β_2 is only very slowly convergent as Egon Pearson notes in the paper ([6]) already referred to Hence the development of the test for samples of less than a hundred would be of little practical value.

8. E. S Pearson, in the paper ([6]) mentioned above, has given 5 per cent. points for $\sqrt{\beta_1}$, *i.e*, the highest value which is likely to be exceeded in only 5 per cent. of the cases. The 5 per cent. values corresponding to each station are given in *column 3* in each of the Tables, under "5 per cent. point for independent distribution."*

* These have the same meaning as that given by Pearson.

9. On this criterion all values of $\sqrt{\beta_1}$ which are greater than the corresponding 5 per cent values should be considered significant. Such values of $\sqrt{\beta_1}$ have been underlined in the *Tables*. The number of such values is 34. One may be inclined to say that these departures from the normal type are significant.

10. But there is another point to be considered. The monsoon current is the main cause of all rainfall in this season. The other contributory causes which help the production of rainfall are the orographical features of the country, the quasi-permanent fronts, the temporary fronts developed during the passage of storms and depressions across the country and the thunderstorms developed by local convection. There is no doubt that there are other cause groups which come into play but of those we have yet no information. Similar cause groups acting with like "valency" should, it appears, give similar departures from the normal value of rainfall. It may therefore be reasonably surmised that the shape of the curve depends only on the nature of the cause groups and their valency. On this assumption the 68 stations can be divided into the following nine groups: stations on (*i*) the West Coast North, (*ii*) the West Coast South, (*iii*) in the Peninsula, (*iv*) on the East Coast and Central India (*v*) in the Gangetic Plain (*vi*) in Assam, (*vii*) on the Himalayas, (*viii*) on the borders of Rajputana and (*ix*) on the Tenasserim and Arakan Coasts.

11. *Tables I* to *IX* indicate this grouping. We may not be far wrong in considering that the stations in any particular group form a random selection, as regards rainfall amounts, from the same population. That is, if we consider, for example, the stations on the West Coast North, we may assume that the rainfall amounts at each of the stations form a random selection from the same population, and as there are 6 stations in that group, there are 6 random selections. Naturally the larger the number of selections, the greater does the highest value of $\sqrt{\beta_1}$ become. If we assume that the population is normally distributed, we have to find out the greatest value of $\sqrt{\beta_1}$, that may be expected in these 6 samples.

12. To calculate this value we may use an investigation by Walker ([7]). The tables he has given in that paper enable us to find out the probable highest value of $\sqrt{\beta_1}$, that may be expected in these 6 random samples. But as this may be considered to be a somewhat low limit of significance, we may find what may be called the 5 per cent. highest value of $\sqrt{\beta_1}$, *i.e.*, the highest value that is likely to be exceeded only in 5 per cent. of the cases. This value can be calculated from the tables given in a paper ([8]) by Savur and Gopal Rao, by multiplying the probable error of $\sqrt{\beta_1}$ by the factors in the table.

13. Strictly speaking, these tables can be applied only when the number of elements in each selection is the same. In our case, as the number of elements (*i.e.*, the number of years) is different, the mean of these was used. With this value, the 5 per cent. highest value of $\sqrt{\beta_1}$ was calculated. It is given in *column 4* of *Table I* under "5 per cent. highest value for related distributions."

14. On our new criterion, all values of $\sqrt{\beta_1}$ in that table which exceed "the 5 per cent. highest value for related distributions" should be considered to indicate a significant departure from normal distribution. There is no value of $\sqrt{\beta_1}$ in *Table I* which exceeds this value. Hence the population, from which our 6 random samples on the West Coast have been selected, may be considered to be normally distributed.

15. A similar test was applied to each of the tables in turn. The 5 per cent. value for each table is given in *column 4*. It can be seen that there are seventeen stations in all in which the value of $\sqrt{\beta_1}$ exceeds the "5 per cent. highest value for related distributions." These values have been underlined twice. Hence

excluding these 17 cases we may say that there is no reason to believe that the monsoon rainfall is not distributed normally. Of these 17 stations four are found in northwest India round the desert region there, two on the leeward side of the Ghats in the Bombay Deccan, and two in the extreme southwest coast of the Peninsula.

16. But still there remains one other point of which our tests have not and could not take cognisance. Consider the values of $\sqrt{\beta_1}$ in *Table I*. Excluding that for Bombay, these values diminish at first as we go down in the table (*i.e.*, South on the map in *Plate II*) and then increase This increase is kept up in *Table II* also Such a regular variation can hardly be attributed to chance. The variations of $\sqrt{\beta_1}$ in *Tables V*, *VII* and *IX* are also more or less regular Although no physical explanation is as yet available for these variations, they should, it appears, be capable of such an explanation

17. In this connection, reference may be made to Philosophical Transactions Vol 190 (1897) in which Karl Pearson and A. Lee have published a discussion on the distribution of the frequency of barometric heights at diverse stations in England ([9]). In that article they note, " putting aside one or two anomalies, we find a continuous and gradual change of frequency constants as we pass from station to station round the coast, and it appears easy to draw the contour lines of equal frequency as it has hitherto been supposed to be to draw isobars " Within limits, a similar remark may be said to apply to monsoon rainfall as suggested in the discussion

18. The 5 per cent points for β_2, given in the tables of Egon S Pearson's paper ([6]) are given for 25 number intervals, beginning with 100 only As 95 is sufficiently near to 100 the 5 per cent. points for β_2 were obtained by extrapolation in the case of the few stations which had only 95 years of data For other stations which have a hundred years' data or more, these 5 per cent points were readily found from the tables. For each of these stations the lower limit of the 5 per cent. point for β_2, is entered in *column* 5 and the upper in *column* 7. The only station in which these limits are exceeded is Shimoga Hence we may say that, excluding Shimoga, the departure of β_2 from normality is not significant There is, unfortunately, no possibility of applying the more stringent test, *i e*, that for related distributions as in the case of $\sqrt{\beta_1}$ in this case, because not more than one station which possesses a record of about hundred years is found in any group , and the distribution of β_2 for a random sample from a normal population cannot be considered to be sufficiently normal even when $n=1{,}000$. However, most of the values of β_2 are sufficiently near 3 to lead one to assume that there is no significant departure from the Gaussian.

19. In conclusion, it may be stated that there seems to be very little justification for an assumption of a non-normal distribution as regards monsoon rainfall over most of the plains of India But one cannot yet say whether the curves are " necessarily " normal

20. When, however, the rainfall is grouped in large divisions as is done by this department for forecasting purposes, the smoothing that is introduced would, it appears, make the distribution conform more truly to the Gaussian type For the three main sub-divisions into which India is divided for purposes of foreshadowing monsoon precipitation, *viz*, the Peninsula, Northwest India, and Northeast India, $\sqrt{\beta_1}$ works up to ·64, ·06 and ·42 respectively, while β_2 is 3·79, 3·35 and 2·80. These are based only on 57 years' data.

21. My heartfelt thanks are due to Dr. S. R. Savur, M.A., Ph D., for guidance at every stage and to Mr. L. S. Mahalingam, M.A., for checking parts of the heavy work involved in the preparation of the paper.

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(5) *R A Fisher* —"Moments and product moments for sampling distributions," 'Proceedings of the London Mathematical Society, (2) Vol XXX, 1929, pp 199-238

(6) *Egon S Pearson* —"Biometrica," Vol XXII, 1930, pp 239-249

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(9) *Karl Pearson and A Lee* —"Philosophical Transactions," Vol 190 A, 1897, pp. 423-469,

Table I (Group I).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches (8)	Standard Deviation. (9)	No. of years of data. (10)
Surat 21° 12′ EN 72° 52′E	+ 31	47			3 54		38 66	13 26	68
Bombay 18° 55′ N 72° 54′ E	+ 07	37		2 38	3 47	3 73	69 13	17 36	114
Mathiran 18° 59′ N 73° 18′ E	− 30	50			3 38		197 85	39 99	60
Ratnagiri 17° 8′ N 73° 19′ E	+ 25	45	70		3 40		94 11	20 54	74
Karwar 14° 48′ N 74° 11′ E	+ 17	47			2 85		107 83	23 98	69
Mangalore 12° 52′ N 74° 53′ E	— 04	47			2 95		111 23	19 04	68

Table II (Group II).

Station (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches (8)	Standard Deviation. (9)	No of years of data. (10)
Tellicherry 11° 45′ N 75° 32′ E	+ 26	47			2 81		105 46	22 64	68
Calicut 11° 15′ N 75° 49′ E	+ 44	46			3 21		89 64	18 30	70
Ponnani 10° 47′ N 75° 58′ E	+ 52	49			3 16		76 07	18 58	61
Palghat 10° 46′ N 76° 42′ E	+ 60	·47	·76		3 02		58 10	15 80	68
Cochin 9° 58′ N 76° 17′ E	+ 77	45			4 01		74 69	16 56	75
Trivandrum 8° 29′ N 76° 59′ E.	+1 11	44			4 91		30 01	10 38	79
Colombo 6° 56′ N. 79° 56′ E.	+1 88	49			8 47		21·15	11·52	62

TABLE III (GROUP III).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches (8)	Standard Deviation (9)	No. of years of data. (10)
Poona . 18° 31′ E. 73° 55′ E	+1 22	41			5 22		20 23	7 92	88
Belgaum . 15° 52′ N 74° 34′ E	+1 30	41			6 52		38 11	9 92	79
Shimoga 13° 56′ N. 75° 36′ E	+ 56	40		2 34	4 76	3 79	20 15	6 62	95
Chitaldrug . 14° 14′ N 72° 26′ E	+ 71	49			3 48		12 32	4 35	62
Manantoddy 11° 48′ N 76 3′ E	+1 07	48			4 20		90 67	26 06	64
Malegaon 20° 32′ N 74° 37′ E	+ 63	46			2 84		17 99	6 64	71
Ahamednagar 19° 5′ N 75° 48′ E	37	45			3 00		18 21	6 23	75
Bijapur 16° 50′ N 75° 4′ E	· 33	46	79		2 26		14 05	5 46	70
Bellary 15° 9′ N 76° 57′ E	+ 25	44			2 58		10 06	4 21	78
Hassan 13 0′ N 76 8′ E	+ 31	49			2 60		16 47	5 98	76
Bangalore . .. 12 37′ E.	+ 68	40		2 34	2 87	3 79	19 24	5 63	55
Akola . 20 42′ N 7 2′ E	+ 72	46			5 34		25 46	8 28	70
Hyderabad . .. 17 20′ N. 78° 30′ E.	+ 75	47			2 46		8 51	7 00	67
Cumbum .. .. 15° 34′ N 79° 9′ E	+ 72	49			3·15		14 32	5 63	62
Madras . .. 13° 4′ N 80° 15′ E	+ 53	·36		2·39	3·52	3 72	15 13	5 14	119
Vellore .. .. 12° 55′ N. 70° 10′ E.	+ 97	·47			3·86		18·84	7·89	69

TABLE IV (GROUP IV).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches. (8)	Standard Deviation (9)	No of years of data. (10)
Balasore 21° 30′ N 86° 58′ E	+ 40	45			2 62		45 06	10 98	72
Puri 19° 48′ N 85° 52′ E	+ 49	45			2 86		38 37	11 62	74
Vizagapatam 17° 44′ N 83° 23′ E	+ 19	48			2 22		22 05	6 88	65
Masulipatam 16° 9′ N 81° 12′ E	+ 82	47			3 03		23 61	7 46	68
Dhamtri 20° 42′ N 81° 36′ E	+ 32	48			2 81		46 61	61 52	64
Rewah 24° 31′ N 81° 20′ E	+ 74	50			3 51		43 33	13 04	60
Nagpur 21° 9′ N 79° 9′ E	— 33	43	80		2 67		40 18	9 12	84
Jubbulpore 23° 10′ N 79° 50′ E	+ 66	43			3 11		49 84	13 60	84
Nowgong 25° 3′ N 79° 30′ E	+ 06	48			3 38		38 90	11 64	64
Indore 22° 44′ N 75° 50′ E	+ 25	48			2 64		30 72	8 14	64
Jalarpatanam 24° 35′ N. 76° 15′ E.	+ 47	·49			3 50		33 60	10 40	61

TABLE V (GROUP V).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches. (8)	Standard Deviation. (9)	No. of years of data. (10)
Calcutta .. .. 22° 32′ N. 88° 24′ E.	+ 81	39		2·35	3 77	3 76	48·22	20 22	102
Berhampore .. .. 24° 6′ N. 88° 23′ E.	+ 04	44			2 34		41·4	9·64	77
Ranchi .. .. 23′ 23′ N. 85° 23′ E.	+ 16	45			3·43		45 07	9·52	73
Monghyr . 25° 23′ N. 86° 30′ E.	+ 28	·44			2 81		39 45	11 04	77
Patna . .. 25° 37′ N. 85° 10′ E.	+ 29	44			2 73		38 74	11·84	78
Allahabad .. .. 25° 28′ N. 81° 51′ E.	+·32	43	75		3 10		34 11	9·92	83
Agra .. .. 27° 10′ N. 78° 5′ E.	+ 20	·43			3 11		23 24	8 00	84
Jaipur .. .. 26° 55′ N. 75° 52′ E.	+ 88	49			4 25		21·35	9 20	63
Hissar .. .. 29° 10′ N. 75° 46′ E.	+ 64	43			2 51		12 81	5 52	81
Lahore .. .. 31° 34′ N. 74° 21′ E.	+ 57	45			3 21		15 29	6 46	74

TABLE VI (GROUP VI).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches. (8)	Standard Deviation. (9)	No. of years of data. (10)
Gauhati .. .. 26° 11′ N. 91° 48′ E.	+ 94	·44			4·41		42 03	9 54	97
Cherrapunji .. .. 25° 16′ N. 91° 46′ E.	+ 83	45	64		4·45		334·78	81·78	73
Dinajpur .. .. 25° 37′ N. 88° 40′ E.	+·57	·45			3·51		56 82	15·32	73

TABLE VII (GROUP VII).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches. (8)	Standard Deviation (9)	No. of years of data. (10)
Darjeeling 27° 3′ N 88° 18′ E	+ 33	47			3 04		99 32	15 58	69
Katmandu 27° 42′ N. 85° 12′ E.	— 00	44	66		2 55		43 81	7 22	79
Almora 29° 35′ N 79° 41′ E	+ 29	41			2 88		30 61	8 14	88
Simla 31° 6′ N 77° 13′ E	+ 70	46			1 91		48 67	13 14	70

TABLE VIII (GROUP VIII)

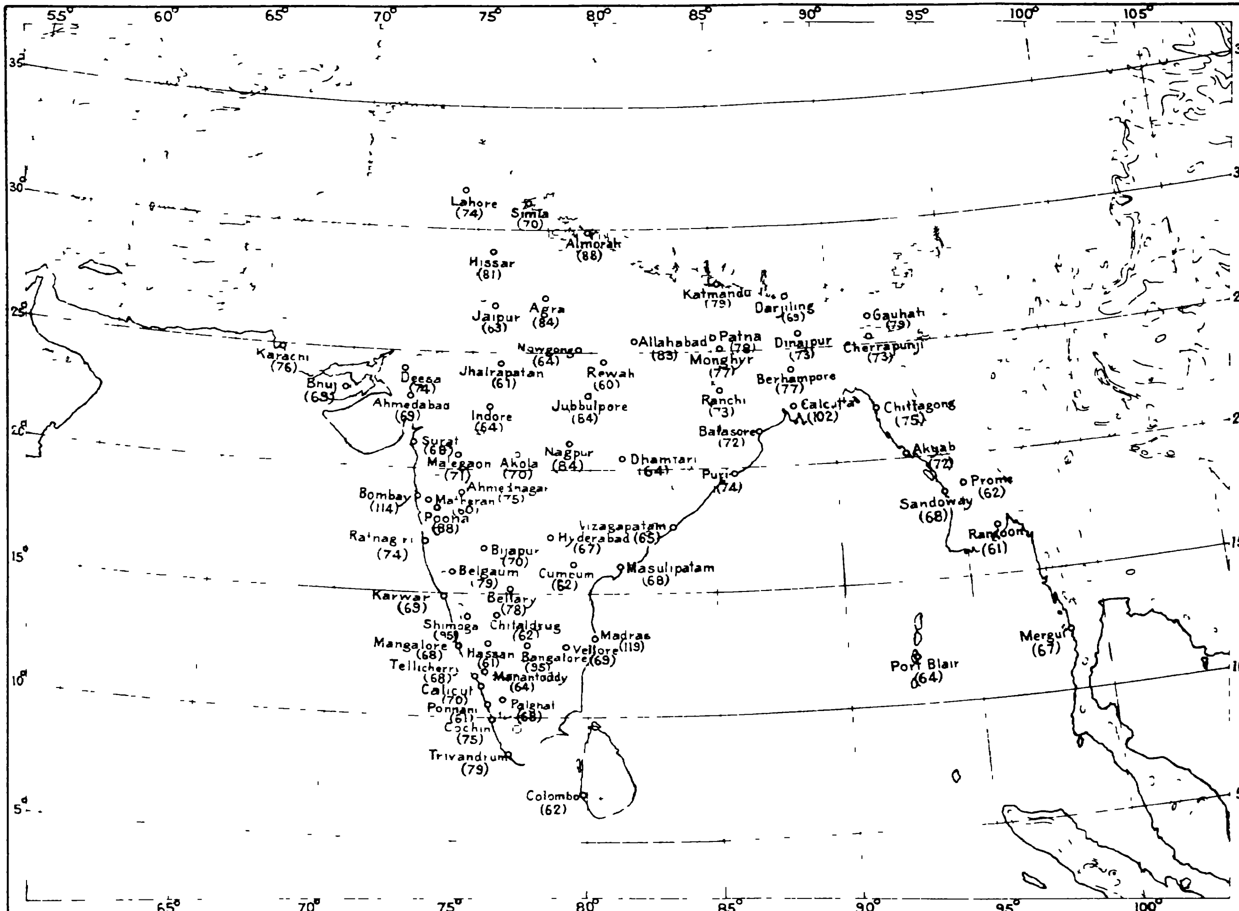
Station.	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches (8)	Standard Deviation. (9)	No. of years of data. (10)
Karachi 24° 51′ N 67° 4′ E.	+1 32	44			3 61		5 76	2 90	76
Bhuj 23° 15′ N. 69° 49′ E	+1 43	47	70		5·84		13 00	7·90	69
Deesa 24° 14′ N 72° 13′ E.	+ 67	45			3 32		22 75	11 12	74
Ahmedabad 23° 2′ N. 72° 38′ E.	+ 83	·47			5 69		29·64	11·76	69

TABLE IX (GROUP IX).

Station. (1)	$\sqrt{\beta_1}$ (2)	5% point for independent distributions of $\sqrt{\beta_1}$ (3)	5% highest value for related distributions of $\sqrt{\beta_1}$ (4)	5% point for lower limit of β_2 (5)	β_2 (6)	5% point for upper limit of β_2 (7)	Normal in inches. (8)	Standard Deviation. (9)	No. of years of data. (10)
Port Blair .. .. 11° 41′ N. 92° 45′ E.	+ 24	48			2 54		66 83	11 94	64
Mergui .. .. .. 12° 27′ N. 98° 35′ E.	— 04	·47			2 58		118 30	16 84	67
Rangoon .. .. 16° 47′ N. 96° 13′ E	—·06	49			3 09		76 85	12 30	61
Prome .. .. . 18° 48′ N. 95° 18′ E.	+1 89	49	·76		9 92		33 78	8·06	62
Sandoway .. .. 18° 28′ N. 94° 25′ E.	—·27	·47			3 30		185 11	29·58	68
Akyab .. .. .. 20° 7′ N. 92° 57′ E.	— 09	46			2 41		170 45	25·72	72
Chittagong .. .. 22° 21′ N. 91° 50′ E.	+ 13	·45			2 80		77 56	16 98	75

M5DGOb—360—8-11-33—GIPS

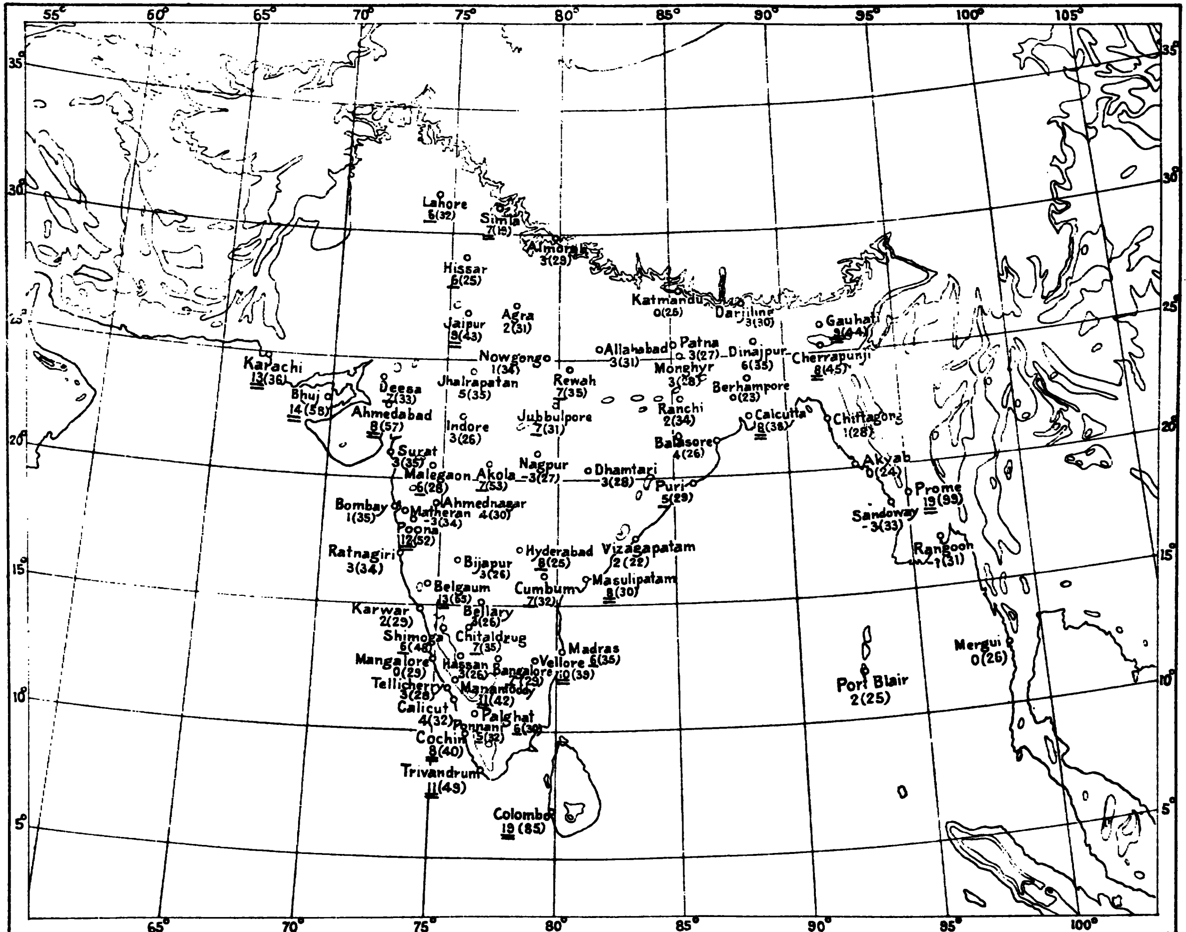
Plate I



Map showing the Stations selected and the number of years of Data used in the Investigation

G P Z O Poona, 1933

Plate II.



Map showing $10x/\beta_1$ and $(10x\beta_2)$

G.P.Z.O. Poona, 1933.

NO-S N 5/53

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A Note on the Rapid Fluctuations of Atmospheric Pressure and the Atmospheric Instability at Peshawar during 1928 and 1929.

BY

S. BASU and S. K. PRAMANIK.

(Received on 30th October 1931.)

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A NOTE ON THE RAPID FLUCTUATIONS OF ATMOSPHERIC PRESSURE AND THE ATMOSPHERIC INSTABILITY AT PESHAWAR DURING 1928 AND 1929.

BY

S. BASU AND S. K. PRAMANIK.

(*Received on 30th October, 1931.*)

Brunt has shown[1] that in stable atmosphere the motion of a small element vertically displaced should be a simple harmonic motion about the original position of the element. The equation derived for this motion is

$$\frac{d^2}{dt^2}(dh) + \frac{g}{T}\left(\beta + \frac{dT}{dh}\right) dh = 0,$$

where h = the height of the element above the earth's surface,

T = the absolute temperature at a height h, so that T is a function of h,

β = the adiabatic lapse rate,

and g = the acceleration due to gravity.

In this equation if the positive value of $\left(\beta + \frac{dT}{dh}\right)$ is taken, the period of oscillation is given by

$$2\pi \Big/ \left\{\frac{g}{T}\left(\beta + \frac{dT}{dh}\right)\right\}^{\frac{1}{2}} \text{ seconds.}$$

As the lapse rate increases from 0 to the adiabatic value, the period increases from about 6 minutes upward. When the lapse rate is equal to the adiabatic, any displaced particle will stay where put. For lapse rates greater than the adiabatic, instability occurs, and the displacement increases exponentially.

If the air is saturated then β must be replaced by the saturated adiabatic lapse rate α, so that α is roughly half the value of β; the period of oscillation in an isothermal saturated air, when $\frac{dT}{dh} = 0$, works out to about 8 minutes, it being as-

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[1] "The period of simple vertical oscillations in the atmosphere."—Q. J. Roy. Met. Soc., Vol. 53, 1927, pp. 30-32.

sumed that the raindrops do not fall out.[1] This assumption seems to be plausible when dealing with oscillations of such small periods.

Fujiwhara and Kanagawa investigated[2] the possibility of using the period of oscillation of the atmosphere, shown by a Sprung's barograph, as an indicator of atmospheric instability. From an examination of 31 cases of barometric oscillations in 1928 with periods longer than 10 minutes but shorter than 30 minutes they suggested that the period of free oscillation, if properly observed, serves as an useful index of the atmospheric stability and proves to be a reliable information for forecasting rain. To test if this suggestion works, 2 years' (1928 and 1929) records of a Shaw and Dine's daily microbarograph by Negretti and Zambra (installed at the Meteorological Office, Peshawar) were examined along with the Peshawar hyetograms for the corresponding period, the hyetograms were obtained from a daily Syphon raingauge by Casella. While tabulating the results from the microbarograms and the hyetograms, the weather remarks for the corresponding days as entered by the observers of the Peshawar Observatory, wherever available, were also taken into account. The results of the examination are given in *Tables 1* to *6* appended at the end.

It will be seen from the *Tables* that in all there were 218 occasions during the two years on which the microbarograph traces show fluctuations with periods 10 minutes or more. Out of these, according to *Tables 1* and *2*, on 110 occasions the fluctuations were definitely associated with condensation of water vapour in the atmosphere to the extent that precipitation was observed at the station itself On the other hand it is significant that, according to *Tables 3* and *4*, there were only 30 occasions in the two years on which rain fell at the station without the microbarograms showing any fluctuations, and that the rainfall recorded on these occasions was mostly very small, being only traces on 21 occasions, 0·1" or less on 7 occasions and more than 0·1" on only two occasions. That is to say, about 82 per cent. of the total number of occasions of rainfall had, associated with them, microbarographic fluctuations.

Tables 5 and *6* show 78 occasions on which the microbarograph traces showed fluctuations of 10 minutes or greater period, but on which rain was not recorded at the station. Out of these, however, there were 21 cases in which the weather remarks entered against each day go to show that on these days the barometric fluctuations were associated with abnormal conditions of the atmosphere, as shown by the occurrence of thunderstorm or duststorm. Regarding the state of the atmosphere on the remaining 57 cases on which fluctuations of periods 10 minutes or more were observed, it is not possible to say anything definitely in the absence of a more detailed weather diary of cloud developments, etc.

The times of incidence of the fluctuations in the microbarograph traces and of the associated subsequent rainfall may also be compared from *Tables 1* and *2*. It is seen that in 70 cases only the exact time of commencement of rainfall could be fixed from the charts of the self-recording raingauge ; in the other cases, when mostly the rainfall was only a trace, the hyetograms failed to show the time of the rainfall and hence it was possible to fix the hours only roughly between which the rainfall occurred.

Taking the 70 occasions on which the time of commencement of rainfall could be fixed exactly, it will be seen that the incidence of the atmospheric fluctuations

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[1] See also " The study of the minor fluctuations of the atmospheric pressure "—by Shaw and Dines. Q. J. Roy. Met. Soc., Vol. 31, 1905, pp. 49.

[2] " On the barometric oscillation with period more than 10 minutes and its use in weather forecasts." Geoph. Mag. Cent. Met. Obsy., Tokyo ; Vol. 1, 1928, pp. 304-306.

shown on the microbarograms preceded the commencement of rain in 62 cases, and followed in only 8 cases. The average interval between the commencement of the fluctuations and the subsequent rainfall is of the order of about 6 hours. Even on those occasions on which the commencement of rainfall could be fixed to be between certain hours, it is possible to find approximately the time of incidence of rainfall or the manifestation of atmospheric instability in 46 cases where adequate remarks on the weather situation have been given by the observers. If these probable cases are also taken into account, it is found that the incidence of the atmospheric fluctuations precedes the commencement of rainfall in 102 cases, follows it in 11 cases and is simultaneous in 3 cases That such an estimate regarding the times of commencement of rainfall is not wholly unjustified is borne out by the fact that when these cases are included the average interval by which the incidence of atmospheric fluctuations precede the commencement of rainfall comes out to be about 5¼ hours, not very much different from 6 hours which was the value obtained by taking into account only definite cases

The periods of fluctuations observed on the microbarograph traces range between 10 minutes and 50 minutes, 15 to 30 minutes being the value which is common. A few microbarograms showing well pronounced pressure fluctuations are reproduced in *Figures 1 7* with the times of associated weather phenomena marked on them

The foregoing discussion of the two year's records appears to support the conclusions of Brunt, Fujiwhara and Kanagawa, and, if properly observed, the period of free oscillation of the atmosphere may serve as a useful factor for forecasting rain. It seems however that the average interval between the incidence of the oscillations of the atmosphere and the commencement of rain is less than 11 to 12 hours and may be only about half as much, *i e*, 5 to 6 hours, at least in the regions represented by Peshawar. No further generalisations can be claimed from an examination of only two years' data at a single station, but we trust that this note, based upon 218 observations, may lead towards a recognition of the necessity for a proper study of the oscillations as indicated by a microbarograph and their relation to atmospheric instability and precipitation.

For a loan of the microbarograms and hyetograms analysed in this note we have to thank Flt Lt. R. G. Veryard, Meteorological Officer, R. A. F., Peshawar, under whose supervision the records were collected. Our thanks are also due to Mr. S. D. Bose of the Meteorological Office, Poona, for help in the analysis of one year's microbarograms and rainfall records.

TABLE 1.

Year 1928. Month.	Date.	Pressure fluctuations. From	To	Rainfall.		Amount.	Interval.	Remarks.
		Hrs	Hrs.	Hrs	Hrs.	Inches.	Hrs. Mins.	
January . .	5	05 10	23 30	From 22 00	To —	01	16 50	
	6	10 00	14 00	„ 23 00	„ —	T	13 00	
	7	10 15	08 45 8th	Bet 10 00	and 16 00	T	—	
				From 20 45	to 03 30 8th	·04		
	12	08 15	16 00	„ 20 00	„ 20 05	T	11 45	
	18	05 40	16 00	Bet 08 00	and 10 00	T	—	
				20 00	10 00 19th	05		
	20	08 00	09 20	From 04 00	to 09 15	21	4 00	Rain preceding.
	23	12 00	19 00	„ 04 15 24th	„ 10 30 24th	12	16 15	
				Bet 10 30 „	and 16 00 „	T		
February . .	6	05 30	07 00	From 08 30	to 24 00	55	3 00	
	9	06 00	07 30	Bet. 08 00	and 10 00	T	—	
	9	11 30	18 00	From 10 30	to 03 30 10th	97	1 00	Rain preceding.
	10	10 30	14 00	„ 14 15	„ 16 45	·05	3 45	
	11	01 00	07 45	„ 05 20 11th	„ 05 50 11th	·04		
				Bet 08 00	and 10 00	T	4 20	After 12-30 on the 11th microbarograph did not record up to 10-00 on the 13th.
				From 19 15 12th	to 10 00 13th	2 45		

March . . .	3	12 00 2nd	09 45 3rd	,,	04 30 3rd	,,	04 35 3rd	03	16 30	☈ 04-45 to 05-00—3rd.
	3	11 00 3rd	24 00 4th	,,	20 45 ,,	,,	18 30 4th	·55	9 45	Intermittent showers; ☈ 19-00 (3) to 08-00 (4).
	8	21 20	02 15 9th	Bet.	16 00	and	08 00 9th	T	—	
	9	05 15	11 30	From	13 30	to	17 30	57	8 15	
				At	20 45		—	T		
	13	11 20	06 45 14th	From	22 50	to	23 40	11	11 30	
				,,	01 45 14th	,,	02 30 14th			
	21	22 00	06 15 22nd	Bet	16 00	and	08 00 22nd	T	—	
	23	20 30 22nd	00 30 23rd	,,	10 00 23rd	,,	16 00 23rd	T	—	
	23	11 00	05 40 25th	From	01 20 24th	to	04 40 24th	17	14 20	
				Bet	10 00 ,,	and	16 00 ,,	T		☈ 03-50 to 04-50—24th.
				From	17 30 ,,	to	18 40 ,,	05		
				,,	21 30 ,,	,,	23 15 ,,			
	25	12 20	08 30 26th	,,	18 45 25th	,,	02 30 26th	1 34	6 25	☈ 18-00—25th to 01-00—26th.
				,,	05 30 26th	,,	06 20 ,,			
	26	17 00	02 00 27th	,,	22 45 ,,	,,	00 30 27th	05	5 45	☈ 23-30 to 24-00—26th.
	27	11 00	06 00 28th	Bet	16 00	and	08 00 28th	T	—	16-30 to 17-00—27th
	28	13 30	05 30 29th	From	17 30 28th	to	19 45 ,,	48	4 00	Severe Δ-storm 18-00 to 18-30—28th.
				,,	23 20 ,,	,,	00 45 29th			
April . . .	5	00 30	04 30	Bet	16 00 4th	and	08 00 5th	T	—	↯ 21-00 to 21-30—4th.
	5	07 00	20 00	From	14 30	to	14 50	05	7 30	13-50 to 16-00—5th.
										☈ 15-15 to 15-50—5th.

TABLE 1—*contd.*

Year 1928. Month.	Date	Pressure fluctuations. From	To	Rainfall.				Amount	Interval.	Remarks.
		Hrs.	Hrs.		Hrs.		Hrs.	Inches.	Hrs. Mins.	
April—*contd.*	14	18 00	04 30 16th	At	18 15 14th		—	T		≡ 17-30 to 20-30—14th, also 21-45 to 23-30—14th
				Bet	10 00 15th	and	16 00 15th	03	0 15	☈ 18-00 to 19-00—14th.
				„	16 00 „	„	08 00 16th	T		☈ 07-45 to 08-45—15th, also 16-00 to 17-00—15th.
	16	14 00	00 30 17th	„	16 00 16th	„	08 00 17th	T	—	
	17	10 30	07 45 18th	From	16 45 17th	to	19 45 „			
				„	22 45 „	„	02 30 18th	·85	6 15	
				Bet.	08 00 18th	and	10 00 „			
	18	14 00	04 30 19th	From	12 15	to	02 00 19th	07	1 45	Intermittent rain, preceding. ☈ 17-30 to 20-30—18th.
	27	03 30	07 00	Bet	16 00 26th	and	08 00 27th	T	—	☈ 22-45—26th to 00-15—27th.
	27	13 30	02 00 28th	At	22 40 27th		—	01	9 10	
May . . .	1	00 30	06 00	Bet	16 00 30 4	and	08 00 1/5	T	—	
	5	02 45	06 00	„	16 00 5th	„	08 00 6th	T	—	≡ 21-00 to 21-30—5th
	6	14 45	02 00 7th	„	16 00 6th	„	08 00 7th	T	—	≡ 20-45 to 24-00—6th ϟ 19-30 to 21-00—6th.
	7	14 00	01 00 8th	From	19 15 7th	to	20 30 „	04	5 15	≡ 20-00 to 22-00—7th. ☈ 20-00 to 21-00—7th
	10	04 00	06 00	Bet.	10 00	and	16 00	T	—	≡ 13-45 to 17-00—10th and ☈ at 16-30—10th

	10	11 00	21 15 11th	At	20 20 10th		—	02	9 20	≡ 18-30 to 21-00—10th and ☈ 20-00 to 22-00—10th
				„	03 15 11th		—			
				From	08 30	to	10 00 11th	11		
				„	19 40 „		20 00 „	05		☈ 18 45 to 19-40—11th
	14	19 30	20 00	Bet	16 00	and	08 00 15th	T	—	☈ 19-30 to 20-30—14th
	19	13 15	07 15 20th	„	10 00 19th	„	16 00 19th	T	—	≡ 14-45 to 16-00—19th.
				„	16 00 „	„	08 00 20th	T		
	20	11 30	15 00	„	10 00	„	16 00	T	—	≡ 14-30 to 18-00—20th.
				„	16 00 20th	„	08 00 21st	T		
	27	20 00	02 00 28th	„	16 00	„	08 00 28th	T	—	≡ 20-30 to 24-30, ↯ 20-00 to 21-00—27th
June . . .	10	14 30	21 00	„	16 00	„	08 00 11th	T	—	≡ 15-30 to 19-00—10th.
	20	14 00	03 30 21st	„	16 00	„	08 00 21st	·04	—	≡ 14-45 to 15-45—20th.
	21	13 00	19 30	„	10 00	„	16 00	T	—	≡ 14-30 to 15-20, also at 18-00—21st.
				„	16 00 21st	„	08 00 22nd	T		
July . . .	7	16 30	17 30	„	16 00	„	08 00 8th	T	—	
	10	12 00	18 30	„	10 00	„	16 00	02	—	☈ 12-30 to 13-30—10th.
				„	16 00 10th	„	08 00 11th	T		
	21	12 00	20 00	„	16 00	„	08 00 22nd	T	—	
	23	11 00	03 45 24th	„	10 00 23rd	„	16 00 23rd	T	—	≡ 19 30 to 20-00—23rd.
				„	16 00 „	„	08 00 24th	T		
August . .	21	14 00	20 30	„	16 00	„	08 00 22nd	T	—	≡ 16-00 to 17-00—21st.
	24	05 00	06 15	From	05 17	to	05 45	·16	0 17	☈ 04-[illegible] to 07-30—24th; also ≡ 04-45 to 05-45—24th.

TABLE 1—*contd.*

Year 1928. Month.	Date.	Pressure fluctuations. From	To	Rainfall.				Amount.	Interval	Remarks.
		Hrs.	Hrs.		Hrs.		Hrs.	Inches.	Hrs. Mins.	
August—*contd.* .	24	15 00	18 30	Bet	10 00	and	16 00	T	—	≡ 15-25 to 16-45—24th.
	28	14 30	18 00	From	15 00	to	16 00	06	0 30	≡ 14-45 to 17-30—28th; ⚡ 15-00 to 15-30—28th
	29	13 00	21 00	Bet.	16 00	and	08 00 30th	02	—	≡ 16-15 to 17-00; also ⚡ 15-45 to 17-00 and again 05-00 to 06-00—30th.
September . .	1	04 30	06 30	Bet.	06 45	,,	08 00	T	2 15	
				From	08 45	to	10 00	·08		
	1	10 30	11 45	Bet.	10 00	and	16 00	·02	—	
				,,	16 00	,,	08 00 2nd	T		
	17	15 30	21 30	,,	16 00	,,	08 00 18th	T	—	≡ 17-30 to 19-30—17th. ↙ in the evening.
	18	15 00	08 15 19th	,,	10 00 18th	,,	16 00 18th	·02	—	
				At	20 30 ,,		—	·10		≡ 15-45 to 16-30—18th. ⚡ 15-50 to 16-00—18th, also ⚡ 20-25 to 20-55—18th
				,,	02 30 19th		—			
				,,	05 15 ,,		—			
October . .			*Nil.*							
November .	12	00 45	06 15	From	00 15	to	00 20	T	0 30	Rainfall preceding
				,,	04 50	,,	05 20			

	12	10 30	11 15	,,	16 30	,,	17 00		6 00	
	12	22 00	08 15 13th	,,	22 30	,,	01 30 13th	48	0 30	
				,,	08 48 13th	,,	08 53 ,,	T		
	13	14 30	03 30 14th	,,	15 00 ,,	,,	15 50 ,,	T	0 30	
				,,	17 45 ,,	,,	19 15 ,,	22		
				,,	21 00 ,,	,,	21 30 ,,			
	27	14 15 26th	08 45 27th	Bet.	07 00 27th	and	08 00 27th	T	16 45	
				,,	08 45 ,,	,,	10 00 ,,	T		
				,,	10 00 ,,	,,	12 00 ,,	07		
	28	14 15 27th	05 00 28th	,,	16 00 ,,	,,	08 00 28th	1 54	—	
				,,	08 00 28th	,,	00 30 29th	·77		
				,,	06 30 29th	,,	08 30 ,,			
December . .	2	17 45	00 30 3rd	,,	16 00 2nd	,,	10 00 3rd	77	—	K 20-15 to 21-30—2nd.
	11	18 30	05 30 13th	,	10 00 12th	,,	16 00 12th	T	—	
				,,	16 00 ,,	,,	08 00 13th	11		
	27	23 15 26th	09 00 28th	From	18 45 27th	to	05 00 28th	·88	19 30	
	28	10 00	17 00	Bet	08 00	and	16 00	28	—	

T means trace of rain

TABLE 2.

Year 1929. Month.	Date.	Pressure fluctuations. From	To	Rainfall.				Amount	Interval.		Remarks.
		Hrs	Hrs		Hrs		Hrs	Inches.	Hrs	Mins	
January . .	23	11 00	11 30	From	11 30	to	13 15	02	0	30	
	24	04 15	08 30	,,	19 50	,,	09 20 25th	38	14	35	
	25	23 30	02 00 26th	,,	23 40	,,	01 00 26th	08	0	10	
	28	04 30	05 00	At	11 40		—	T	7	10	
	28	16 45	23 30	From	17 15	to	19 00	·16	0	30	Δ-Storm 17-10 to 18-00 L T
	29	11 00	01 00 30th	,,	20 50	,,	21 15	01	9	50	
	30	22 00	05 25 31st	,,	03 00 31st	,,	06 30 31st	14	5	00	Snowfall—31st.
February . .	7	19 21	07 36 8th	,,	01 40 8th	,,	02 45 8th	·03	6	19	
				,,	08 30 ,,	,,	21 00 ,,	31			
	10	02 00	03 30	,,	19 37	,,	21 37	·09	17	37	
	21	03 00	07 15	,,	16 00 21st	,,	01 15 22nd	·17	6	00	
		10 00 21st	04 00 22nd								
March . . .	17	18 00	07 00 18th	,,	20 00 17th	,,	21 00 17th	·01	2	00	≡ T ↯ 18-30 to 21-00—17th.
	21	16 15 21st	10 15 *24th*	Bet	16 00 21st	and	08 00 22nd	T	2	45	≡ 17-45 to 18-50—21st
				From	18 05 22nd	to	22 00 ,,	1 07			☈ 18-30 to 20-30—22nd.
				.	14 45 23rd	,,	17 45 23rd	1 07			T ↯ r Δ (severe) 14-40 to 15-20—23rd.
	24	14 00	18 45	,,	15 35 24th	,,	15 50 24th	01	1	35	

	25	21 15 24th	03 00 25th	At	01 00 25th		—	·02	3	45	
	26	14 30	16 45	Bet	16 00	and	08 00 27th	T	2	15	≋ 15-35 to 16-40, ☈ 16-45 to 17-00—26th
April . . .	1	17 30	24 00	,,	16 00	,,	08 00 2nd	T	5	00	≋ 18-00 to 19-00; oscillations of large amplitude at 22-30 hours when rain probably fell
	4	18 30 3rd	06 00 4th	From	00 15 4th	to	04 10 4th	·02	5	45	
	4	13 30	18 20	,,	12 20	,,	15 50	·05	1	10	☈ 15-15 to 16-00; *rain preceding*, but ☈ following
	18	19 15	01 45 19th	,,	20 30	,,	22 15	·10	1	15	☈ 20-00 to 21-30—18th.
	19	19 45	23 00	Bet	16 00	and	08 00 20th	T	0	0	☈ 19-00 to 21-30—19th.
	22	15 20	23 30	,,	16 00	,,	08 00 23rd	T	0	0	≋ 15-00 to 18-00; ☈ 15-00 to 15-30—22nd
	25	02 30	10 00	From	08 50	to	09 30	06	6	20	
	25	14 00	23 00	,,	14 45	,,	15 05	90	0	45	≋ 14-45 to 15-00, T ↯ Δ—15-00 to 15-30; ☈ 19-00 to 19-30.
May . . .	7	02 00	24 00	Bet	16 00 6th	and	08 00 7th	T	0	15	≋ & ☈ 02-15 to 03-00—7th.
	12	16 45	08 15 13th	,,	16 00	,,	08 00 13th	T	2	00	≋ 17-30 to 18-45—12th.
	13	16 15	04 30 14th	,,	16 00	,,	08 00 14th	T	3	00	≋ 18-15 to 20-30—13th.
	15	17 00	07 30 16th	,,	16 00	,,	08 00 16th	T	1	30	≋ 17-30 to 18-30—15th
	23	15 30	23 00	,,	10 00	,,	16 00	T	0	30	≋ 15-30 to 16-30—23rd. ☈ 17-15 to 20-30—23rd.
	24	03 15	06 45	,,	16 00 23rd	,,	08 00 24th	T	3	30	
	24	16 00	01 15 25th	,,	10 00 24th	,,	16 00 ,,	T	0	0	≋ followed by ☈ 16-15 to 17-30—24th.
				,,	16 00 ,,	,,	08 00 25th	05			
	25	14 20	04 00 26th	,,	10 00 25th	,,	16 00 ,,	T	1	30	

TABLE 2—*contd.*

Year 1929. Month.	Date.	Pressure fluctuations. From	To	Rainfall.				Amount.	Interval.		Remarks.
		Hrs.	Hrs.		Hrs.		Hrs.	Inches.	Hrs.	Mins.	
June . . .	20	04 30	10 00	Bet	10 00	and	16 00	T	6	00	≡ 13-30 to 14-30 and 15-30 to 16-30—20th.
	20	12 15	07 00 21st	„	16 00	„	08 00 21st	·12	3	45	☈ 13-45 to 16-00—20th and also 02-15 to 07-30—21st.
	21	14 00	08 00 22nd	„	10 00 21st	„	16 00 21st	T	2	00	☈ 15-40 to 16-30—21st, sharp oscillations 14-00 to 19-00—21st.
				„	16 00 21st	„	08 00 22nd	T			☈ 05-00 to 06-00—22nd.
	25	09 30	23 30	„	08 00	„	10 00	T	0	30	☈ 10-00 to 19-00—25th.
				From	11 40	to	13 00	·08			
July . . .	2	16 45	03 30 3rd	Bet.	16 00	and	08 00 3rd	T	8	45	☈ 01-30 to 02-00—3rd.
	3	14 45	19 45	„	10 00	„	16 00	T	1	15	≡ 15-30 to 16-15—3rd.
	4	14 50	21 00	„	16 00	„	08 00 5th	T	0	40	≡ 15-00 to 15-30—4th. ☈ 15-00 to 17-50—4th.
	12	00 30	09 00	„	08 00	„	10 00	T	8	00	☈ 07-30 to 08-30—12th.
	12	12 30	09 00 13th	„	16 00	„	08 00 13th	T	11	30	
	14	12 00	15 30	From	14 45	to	15 30	T	2	45	
	17	16 15	05 30 18th	Bet.	16 00	and	08 00 18th	T	11	45	☈ 04-00 to 05-00—18th.
	20	03 00	09 30	From	04 35	to	06 07	1·28	1	35	☈ 04-00 to 07-48—20th.
	22	23 30 21st	09 20 22nd	„	00 45	„	08 30	1·48	1	15	☈ 23-45 (21st) to 03-00 (22nd.).

	24	02 45	09 45	,,	02 05	,,	06 00 (probably) pen sticking	2 69	0	40	*Rain preceding* ☈ 02-00 to 06-30—24th. 2 3″ recorded upto 04-30
	24	12 30	18 30	,,	23 30	,,	04 00 25th	1 26	11	00	☈ 23-30—24th to 02-00—25th.
August . .	1	22 15 31/7	04 45 1 8	,,	02 40 1/8	,,	03 00 31/8	·04	4	25	☈ 19-00 to 20-00—31st July; also 02-00 to 03-30—1st Aug.
	5	14 00	15 45	,,	14 55	,,	15 15	04	0	55	☈ 14-30 to 16-30—5th
	7	16 30	17 00	,,	16 45	,,	17 10	23	0	15	S̶ 16-35 to 16-45, ☈ 16-45 to 17-15; record of microbarograph incomplete.
	15	14 00	19 35	Bet	10 00	and	16 00	T	1	30	☈ 15-15 to 15-45—15th
	17	15 45	18 45	From	16 40	to	16 45	T	0	55	S̶ 16-25 to 17-25; ☈ 17-35 to 17 50.
	18	15 45	19 00	Bet	16 00	and	08 00 19th	T	0	15	☈ 16-00 to 16-10; also 21-00 to 24-00.
	21	11 00	19 00	,,	16 00	,,	08 00 22nd	T	13	00	
	22	17 30	21 30	From	17 45	to	19 30	T	0	15	
	23	04 30	05 15	,,	04 40	,,	13 50	43	0	10	
				,,	21 45	,,	13 30 24th	1 17			
	26	03 45	04 30	,,	09 45	,,	11 50	89	6	00	
	26	10 45	11 15	At	16 45		—	T	6	00	
				From	20 20	to	22 30	·03			
	27	12 00	18 00	,,	07 35	,,	23 45	1 40	4	25	Oscillations very feeble; *rain preceding.*
September . .	1	15 30	21 30	Bet	16 00	and	08 00 2nd	T	4	00	S̶ 18-30 to 19-45; ☈ 19-00 to 20-00—1st
	20	14 00	04 30 21st	,,	16 00	,,	08 00 21st	T	9	00	☈ 22-30 to 23-30—20th
October . .	11	19 00	00 45 12th	,,	16 00	,,	08 00 12th	T	3	00	S̶ 20-30 to 21-45, ☈ 19-00 to 03-30—12th
	15	06 00	13 50	From	11 07	to	12 45	·12	5	07	☈ 11-00 to 11-15 and 11-30 to 11-45.

TABLE 2—*contd.*

Year 1929. Month.	Date.	Pressure fluctuations. From	To	Rainfall				Amount.	Interval.	Remarks.
		Hrs.	Hrs.		Hrs.		Hrs.	Inches.	Hrs. Mins	
November . .	2	17 45	00 30 3rd	Bet	16 00	and	08 00 3rd	T	6 15	
	12	01 30	10 30	„	10 00	„	16 00	T	11 30	
December . .	5	18 30 4th	06 00 5th	From	01 55 5th	to	03 25 5th	·12	7 25	
	9	04 15	08 30	Bet	08 00	and	10 00	T	4 45	
				From	13 25	to	14 15	01		
	10	01 45	05 30	„	05 15	„	08 05	04	3 30	
				Bet.	08 05	and	10 00	02		
	10	12 15	14 15	„	10 00	„	16 00	T	0 45	
	11	23 00 10th	04 15 11th	From	22 00 10th	to	13 30 11th	30	1 00	*Rain preceding.*
	16	18 00	00 15 17th	„	22 50	„	24 00 16th	14	4 50	K 22-45 to 23-15—16th
	17	11 00	21 00	Bet	10 00	and	16 00	T	2 00	
	18	13 15	24 00	From	15 05	to	18 15	05	1 50	
				„	23 15	„	10 40 19th	36		

T means trace of rain

Table 3.

Rainfall without any associated pressure fluctuations.

Year 1928. Month	Date	Rainfall.		Amount.	Remarks
		Hrs	Hrs	Inches.	
January .	14	At 21 00	—	T	
	26	From 17 15	to 24 00	03	
	29	„ 16 45	„ 17 15	02	
February	5	At 19 30	—	T	
	8	„ 17 00	—	T	
	13	Bet 16 00	and 08 00 14th	T	
	15	At 08 20	—	T	
	19	Bet 08 00	and 10 00	T	
	19	„ 10 00	„ 16 00	T	
March .			*Nil*		
April .			*Nil*		
May . .	3	Bet 08 00 3rd	and 08 00 4th	T	13 00 to 16-00 and also 17 15 to 19-00—3rd.
June . .			*Nil.*		
July . .			*Nil*		
August . .	8	Bet. 16 00	and 08 00 9th	T	19-00 to 21-00—8th.
September .	16	„ 16 00	„ 08 00 17th	T	17-00 to 18-00—16th. in the evening.
October .			*Nil*		
November	29	Bet. 16 00 29th	and 08 00 2nd Dec	76	Intermittent rain.
December .	30	„ 10 00	„ 16 00	T	

*T means trace of rain.

TABLE 4.

Rainfall without preceding pressure fluctuations.

Year 1929. Month.	Date.	Rainfall.				Amount.	REMARKS.
			Hrs.		Hrs	Inches.	
January	22	Bet	16 00	and	10 00 23rd	T	
February .	12	From	13 45	to	01 30 13th	·08	
March . .					*Nil.*		
April	6	Bet	16 00	and	08 00 7th	T	☈ 19-15 to 19-40 -6th
May	16	„	16 00	„	08 00 17th	T	
June . .	11	„	16 00	„	16 00 13th	T	Traces intermittently.
July . .	25	From	09 00	to	14 40	07	☈ 23-30—24th to 02 00 —25th.
		At	19 45		—	T	
	26	Bet.	08 00	and	10 00	T	
	31	From	04 20	to	09 30	10	
August . .	1	Bet	16 00	and	08 00 2nd	T	☈ 19-30 to 22-00—1st and 02-00 to 05-00—2nd
	16	„	16 00	„	08 00 17th	T	
	18	At about	07 00		—	T	
	25	Bet.	10 00	and	16 00	T	
		From	23 52	to	00 45 26th	·01	
September .					*Nil.*		
October .	12	Bet	16 00	and	08 00 13th	T	☈ 19-45 to 20-00—12th
	22	„	10 00	„	16 00	T	
November .					*Nil*		
December .	13	From	18 15	to	23 30	07	
	14	„	12 25	„	14 50	14	

T means trace of rain

Table 5.

Pressure fluctuations without subsequent rainfall.

Year 1928. Month.	Date.	Pressure Fluctuations. From	Pressure Fluctuations. To	Remarks about weather.	Interval.	Remarks.
		Hrs.	Hrs.		H. M.	
January .	3	10 00	19 30			
	4	10 30	14 20			
	17	10 00	01 00 18th			
February .	25	11 30	17 00			Not well defined.
	26	11 30	17 30			
	27	19 00	00 30 28th			
	29	11 00	02 30 1st Mar.			
March . .	1	22 15	00 20 2nd			
	8	12 10	16 30			
	29	12 30	14 30 30th			
	31	13 30	00 30 1st April			
April . .	2	11 30	03 30 3rd			
	10	22 00	00 45 11th			
	13	21 45	03 00 14th			
	23	13 30	04 00 24th	18-00 to 18-30—23rd. 22-00—23rd.	5 00	
May . .	8	13 30	24 00			
	18	16 00	03 30 19th			
	25	23 30	—			
	26	19 30	02 00 27th	20-30 to 21-00—26th, also 22-30 to 01-30—27th.	6 00	Not well defined.
	27	11 45	13 00			
June . .	8	13 30	17 30	13-00 to 14-00—8th.	0 30	
	11	15 00	17 00			
	16	00 30	11 00	10-15 to 11-15—16th.	9 45	
	19	14 30	21 00	14-45 to 19-00—19th.	4 30	

TABLE 5—*contd.*

Pressure fluctuations without subsequent rainfall.

Year 1928. Month.	Date.	Pressure Fluctuations. From	To	Remarks about weather.	Interval.	Remarks.
		Hrs	Hrs.		H. M.	
June—*contd.* .	23	15 30	18 30	15-50 to 17-00—23rd	1 30	
	24	16 30	18 00			
	30	19 00	08 30 1st July	15-30 to 16-10—30th	2 50	
July . .	1	13 00	22 30	13-30 to 20-00—1st.	7 00	
	4	21 30	04 00 5th			
August . .	4	16 30	21 00	17-00 to 19-00—4th.	2 30	
	7	15 00	21 00	16-00 to 18-20—7th.	3 20	
	15	16 00	—			
September .	5	16 00	—	16-00 to 16-20—5th.	00	
	11	14 00	19 00	14-15 to 15-45—11th	1 45	
	13	15 00	01 00 14th	18-25 to 19-05—13th in the evening.	4 05	
	16	13 30	21 00	17-00 to 18-00—16th. in the evening.	4 30	
October .				*Nil.*		
November .	24	22 30	05 00 25th			
December .	10	00 00	10 00			
	22	07 30	23 30			

TABLE 6.

Pressure fluctuations without subsequent rainfall.

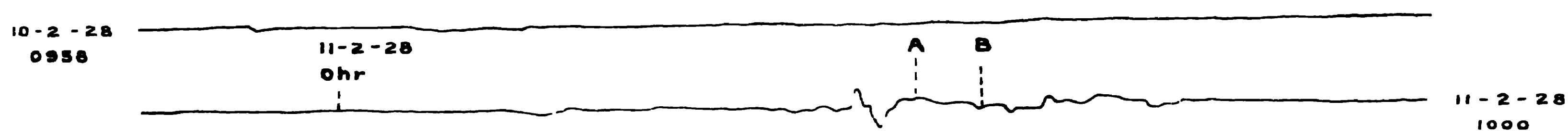
Year 1929. Month.	Date.	Pressure Fluctuations. From	To	Remarks about weather.	Interval.	Remarks.
		Hrs.	Hrs.		H. M.	
January .	9	16 20	04 00 14th			Intermittently.
	15	19 30	07 00 16th			Fine embroidery superposed.
	23	19 00	24 00			
February .	11	01 00	02 00			
	25	09 00	03 00 27th			
March . .	4	18 30	24 00			
	16	19 30	09 00 17th			Feeble; marked after 02-00—17th.
	19	21 30	23 15			
	25	23 00	23 30			
	28	23 00	02 00 30th			
	31	23 30	10 00 1st April			Feeble after 08-00—1st.
April . .	3	02 30	13 30			
	5	01 45	02 30			
	23	23 15	06 30 24th			
	28	22 45	03 00 29th	15-00 to 15 45—28th.	7 00	
	29	23 30	01 45 30th			
May . .	1	00 00	08 00			
June . .	3	18 20	24 00			
	24	20 30	06 00 25th			
	30	13 00	20 00			
July . .	6	00 00	06 00			
	13	17 15	23 30			
	28	10 00	17 15	09-45 to 15-30—28th.	2 45	
August . .	2	13 30	14 25	03-15 to 03-30—3rd.	13 30	
	3	15 45	09 00 4th	21-15 to 24-00—3rd.	5 30	
	4	12 30	20 00			
	5	04 30	08 00			

TABLE 6—*contd.*

Pressure fluctuations without subsequent rainfall.

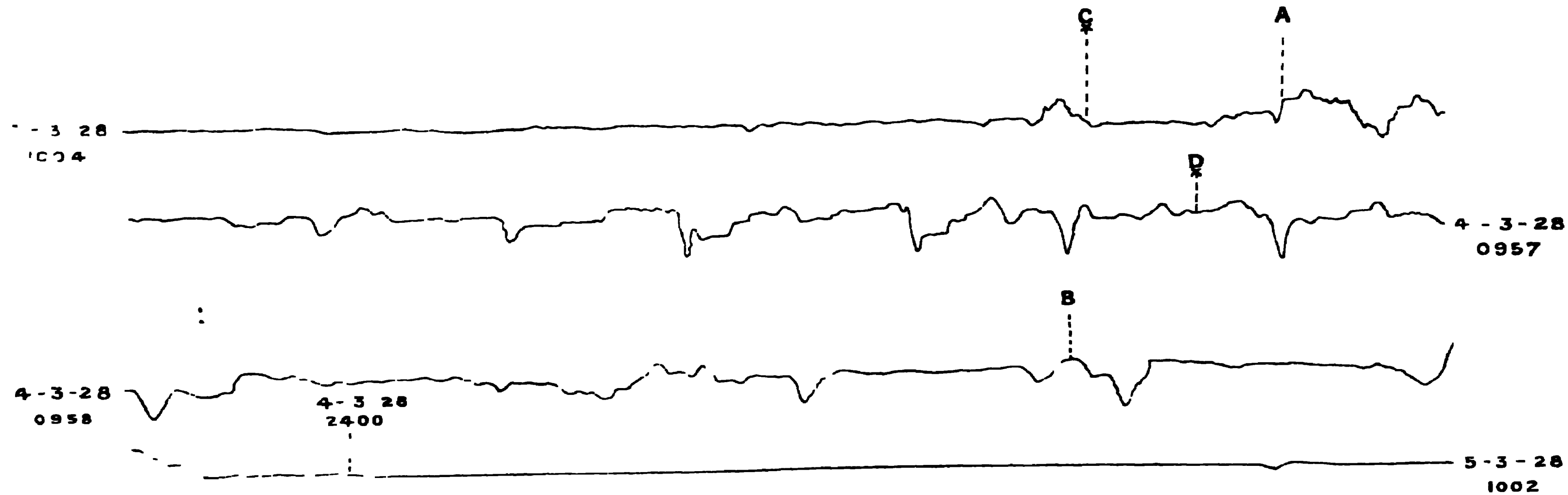
Year 1929. Month.	Date.	PRESSURE FLUCTUATIONS. From		Remarks about weather	Inter-val.	REMARKS.
			To			
		Hrs.	Hrs.		H. M.	
	21	04 00	08 30			
	31	16 30	20 30			
September .	12	16 00	17 45			
	13	02 00	04 15			
	13	15 15	20 00			
	18	20 00	22 15	17·00 to 18·00 ; 19-15 to 20-15—18th.	0 00	
October .	2	05 25	21 30	05·00 to 05·30	0 00	
	10	15 45	22 00			
November .	1	23 00	02 15 2nd	17 40 to 19·00—1st.	4 00	
	25	07 40	09 45			
December .	8	04 30	24 00			
	28	18 00	21 30			

MGIPC—M—VIII-3-196—28 6-33—360.



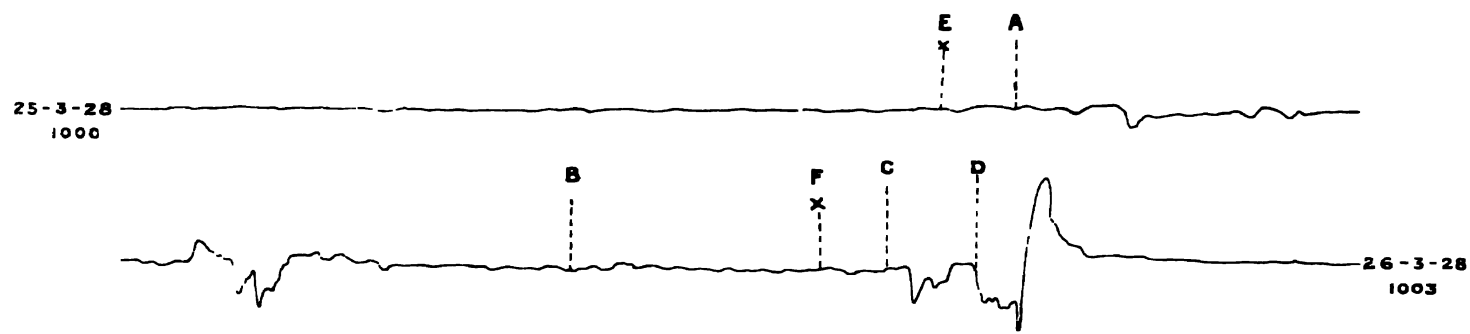
04 inch rain between 0520 (A) and 0550 (B)

Fig. 1



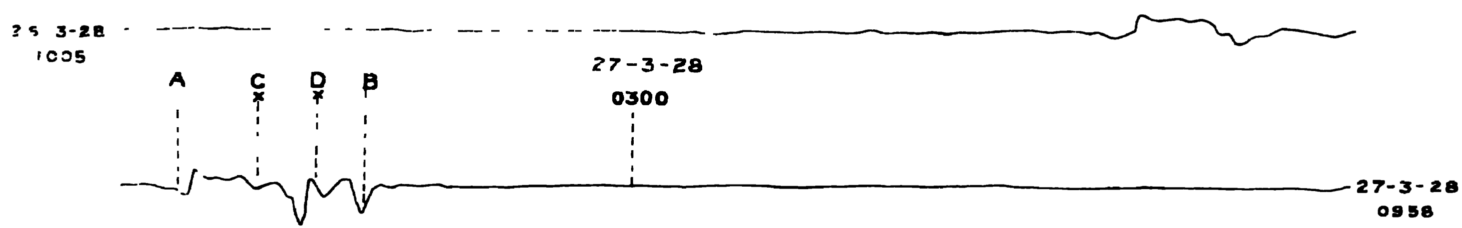
Intermittent showers (55 inch rain) between 2045—3rd (A) and 1830—4th (B)
Thunderstorm at 1900—3rd (C) and 0800—4th (D)

Fig. 2



Rain between 1845—25th (A) and 0230—26th (B); also
,, 0530—26th (C) and 0620—26th (D), Total amount 1·34 ins
Thunderstorm 1800—25th (E) to 0100—26th (F)

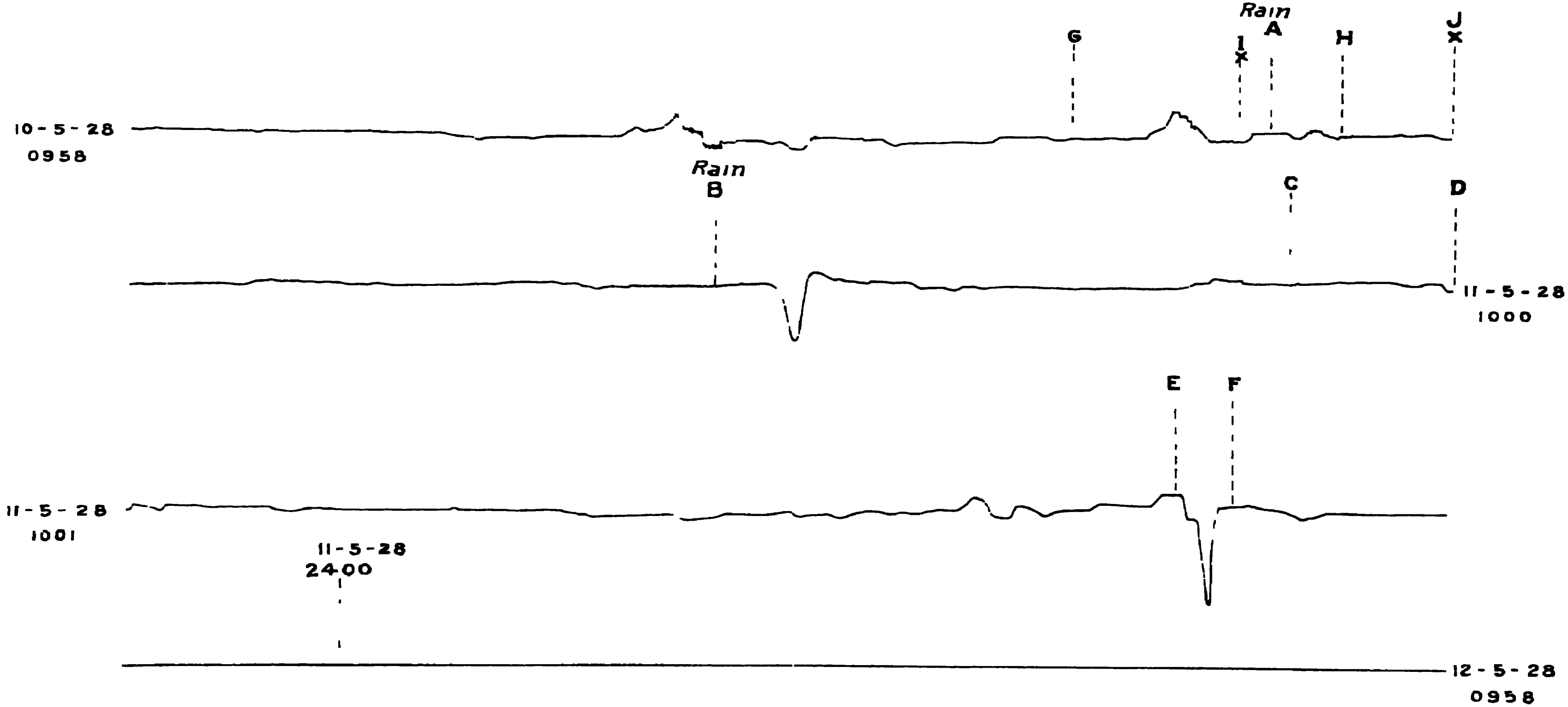
Fig. 3



05 inch rain between 2245—26th (A) and 0030—27th (B)
Thunderstorm ,, 2330—26th (C) and 2400—26th (D)

Fig 4

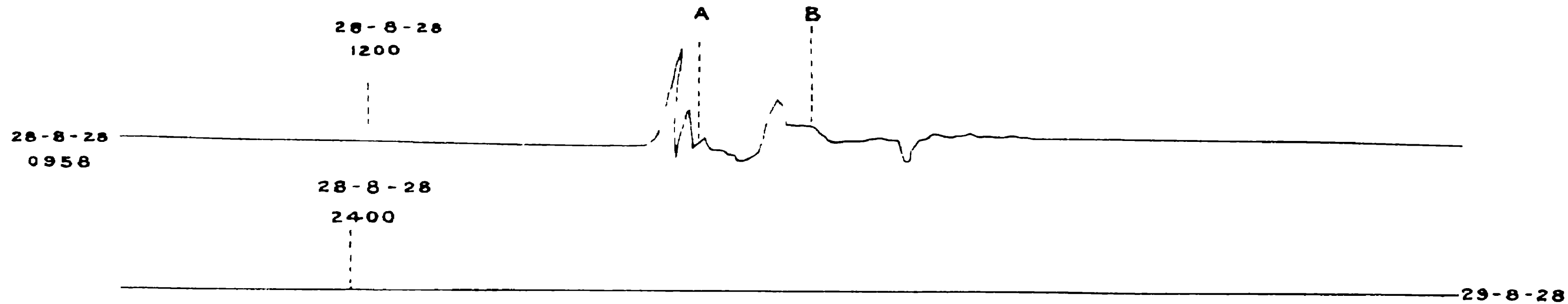
Offset G P Z e 1939



Rain at 2020—10th (A) and at 0315—11th (B) —Total amount 02 inch
,, from 0830—11th (C) to 1000 11th (D) — ·11 inch
,, ,, 1940—11th (E) to 2000—11th (F) — ·05 inch
Duststorm 1830—10th (G) to 2100—10th (H)
Thunderstorm 2000—10th (I) to 2200 10th (J)

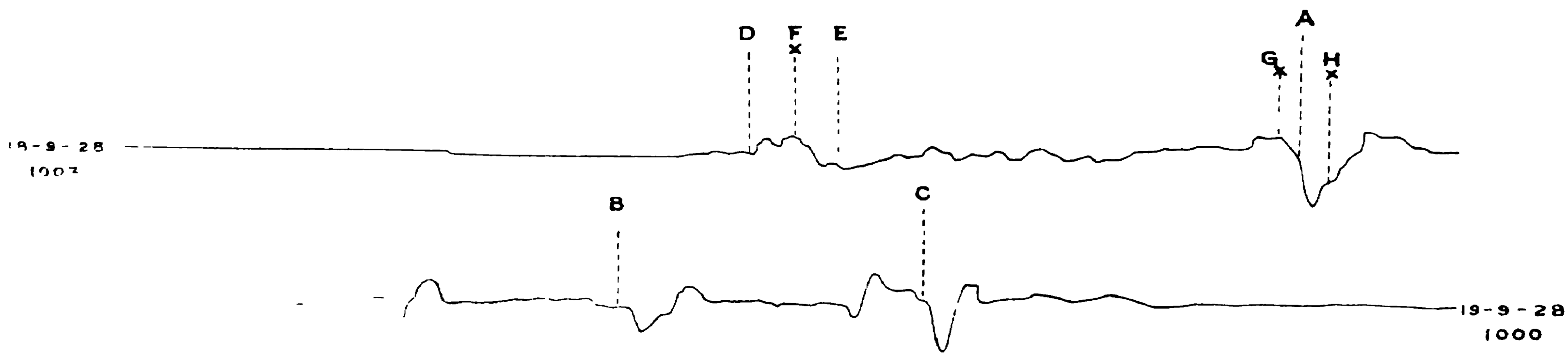
Fig 5

Offset G P & C Poona, 1933



06 inch rain 1500—28th (A) to 1600—28th (B)

Fig 6



Rain 2030 – 18th (A)
0230 – 19th (B)
0515 – 19th (C)

also 1600—18th with Thunderstorm (F)
Duststorm 1545—18th to 1630—18th (D—E)
Thunderstorm 2025—18th to 2055—18th (G—H)

Fig. 7.

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A Preliminary Study of Rainfall at Quetta

BY

A. K. ROY, B.A., B.Sc., and R. C. BHATTACHARYA, M Sc.

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A PRELIMINARY STUDY OF RAINFALL AT QUETTA

BY

A. K. ROY, B.A., B.SC., AND R. C. BHATTACHARYA, M.SC.

(*Received on 30th March 1932*)

Summary—The rainfall records of the Quetta observatory for the period, July 1926 to June 1931 have been analysed. Tables showing the hourly variations of rainfall amount, frequencies of occasions of rainfall and average amount of precipitation for each hour with rain during the various seasons have been given.

The study of winds at 0·5 Km above ground and 3 Kms above sea level over Quetta on rainy days has led to some useful conclusions in regard to the forecast of rainfall at Quetta and its neighbourhood.

1. The Quetta city lies on a valley at the head of the Bolan Pass at a height of about 5,500 ft above mean sea level. The R. A. F. Meteorological observatory is situated near the aerodrome about two miles away from the city, the nearest hills being at a distance of four to five miles to the north and east of the observatory.

A continuous record of the hourly values of rainfall at Quetta was obtained from July 1926, when a self-recording rain-gauge of the tilting bucket type was installed, with the rim of the funnel at a height of 2 ft 6 ins above ground, in the observatory enclosure at a distance of about 50 ft to the north of the office building. Other R. A. F. buildings in the vicinity of the enclosure are at a sufficient distance not to vitiate the exposure of the rain-gauge, which may be considered to be quite satisfactory.

2. Meteorologically, the year at Quetta may be divided into four main seasons, *viz.*,

(1) Winter period- December to Mid-April
(2) Post-Winter period- Mid-April to June
(3) Summer (or Monsoon) period- July to September
(4) Pre-Winter period- October and November

Unlike over other parts of India, the monsoon plays only a minor part in the production of rainfall at Quetta, where the winter characteristics of weather prevail during the greater part of the year. The usual nomenclatures of "pre-monsoon" and "post-monsoon" for the transition periods have, therefore, been substituted by "post-winter" and "pre-winter", respectively.

In the winter period, disturbances from the west approach north-west India and affect north Baluchistan on about four to five occasions on the average per month. The frequency of approach and the nature of such disturbances remain more or less

the same from December to mid-April. The monsoon rains over this part of the country generally occur in July and August, the first advance of the south-west monsoon reaching this region only about the beginning of July or towards the end of June. September is the driest month at Quetta, but the little precipitation that occurs in this month is caused by an occasional revival of the south-west monsoon The remaining months of the year, mid-April to June, and October and November, may be classified as post-winter and pre-winter periods, respectively. During the former period, the western disturbances continue to affect north Baluchistan but are less frequent, and, as they gradually recede to higher latitudes and are comparatively feeble, the disturbed weather caused by them is generally of a more localised character Further, rainfall during this period is not always associated with a western disturbance but may also be caused by the development of a local depression with the intensification of the seasonal low over Sind and Baluchistan The winter characteristics of weather over north Baluchistan begin to develop about the beginning of October, when the western disturbances, which are absent in the monsoon season, commence to make their appearance over the frontier Owing to their general feebleness, comparatively less frequency and passage through regions of higher latitudes, they do not, however, cause sufficient precipitation until December

3 *Table I* gives the hourly distribution of rainfall amount (total of five years, July 1926 to June 1931) in different months and seasons as well as for the whole year The comparison of the figures in the last two columns of the table shows that, on the average, rainfall per annum during the period under consideration was somewhat less than normal The month of August was remarkably dry while February and December were wetter than usual *Table II* gives the total number of times in the five years under consideration in which different hours of the day were associated with rainfall (0·01″ or more) in various seasons The above hourly values have also been expressed as percentages of the total number for each season, and the percentage frequencies given in brackets *Table III* gives information similar to that in *Table II*, the only difference being that, in this table, only those hours have been included in which precipitation amounted to 0·10″ or more. In *Table IV* is given the average amount of precipitation for each hour with rain, the figures being obtained by dividing the amounts under different hours in *Table I* by the corresponding figures in *Table II*.

Table I shows that the amount of rain in any hour is highest in the winter season, the total amount in winter during the five years under consideration constituting more than 80 per cent of the total precipitation during the whole period In all the four seasons, there appears to be a preponderance of rainfall during the afternoon hours, the effect being most marked in the monsoon period, July to September *Table II* shows that the chances of precipitation occurring at different hours are more or less equally distributed in the winter season, while in the monsoon the occurrence of rainfall is practically restricted to the afternoon and evening hours As much as 88 per cent of occasions of rainfall during the latter season are between 1300 and 2200 hours, and nearly 70 per cent of total rainfall in the five years under consideration occurred between 1300 and 1900 hours The transition (post-winter and pre-winter) periods exhibit a preponderance of occurrences of rainfall in the afternoon hours, but there is a fair distribution at other hours also It is seen from *Table III* that rainfall amounting to 10 cents or more is practically restricted to the afternoon hours except in the winter; in this season precipitation of this amount may occur at all hours, although the frequency is greatest in afternoons and evenings.

Rainfall during the winter, and to a certain extent in the two transition periods, is associated with the disturbances which enter north-west India from the west. The rainfall in winter is, therefore, largely of the frontal type, and, consequently, the time of its occurrence does not show any marked preference for a particular period

of the day. It will, however, be seen from *Table III* that precipitation of comparatively large amounts occurs somewhat more frequently in afternoon and evening owing to the greater instability of the atmosphere at those hours. In the monsoon season, rainfall at Quetta is rarely caused by the direct influence of the westward moving depressions from the Bay of Bengal, but chiefly occurs as a result of the occasional incursions of the monsoon into the strongly heated region to the west of the Indus. The instability set up on such occasions under the strong insolation in afternoon seems to be the most important factor in the production of rainfall during this season. Rainfall in monsoon is generally associated with thunder and lightning, *Table V*, giving the frequencies of thunderstorms at Quetta in different months, confirms this statement.

Tables II and *III* are of interest inasmuch as they confirm the existing ideas regarding the difference in the character of rainfall in the two seasons. The distribution of percentage frequencies of occurrence of rainfall at different hours in the two transition periods shows the mixed characteristics of the winter and monsoon seasons.

4. Normal percentage frequencies of morning winds in eight directions at Quetta, at 0.5 Km. above ground and 3 Kms. above sea level and also their frequencies on rainy days at these two heights are given in *Tables VI* and *VII*, and shown graphically in *Fig. 1* (*a* to *h*). It is found that in winter and the transition periods the frequency of winds with southerly components on rainy days is greater than the normal frequency based on all days, while in the monsoon season NE'ly to SE'ly winds at 0.5 Km. and N'ly to E'ly winds at 3 Kms. are more frequent on rainy days than normally. Thus the backing of the prevailing W'ly to NW'ly winds towards S indicates the possibility of rainfall at Quetta except in the monsoon season, when one should expect the greatest chance of precipitation if the wind backs towards E or NE. It would thus appear that winter rains, and rainfall in the post-winter and pre-winter periods are chiefly due to the moisture drawn from the Arabian sea, while in the monsoon season the easterly rain bearing winds are partly drawn from the Arabian sea and are partly a continuation of the deflected current of the Bay monsoon.

5. In order to find out the distribution of rainfall amounts according to different directions of winds, the frequency of wind directions at 0·5 Km. above Quetta and 3 Kms. above sea level, when available, on rainy days during the various seasons, together with the amounts of precipitation corresponding to different directions, have been given in *Tables VIII* and *IX*. Three different cases have been considered, *e.g.*, (*i*) winds of all velocities, (*ii*) winds with velocity -- or > 8 m. p. h., and (*iii*) winds with velocity -- or > 16 m. p. h. In this connection, morning or afternoon winds have been taken into consideration according as the rainfall occurred between 0800 hrs. and 1700 hrs. or between 1700 hrs. and 0800 hrs. on the following morning. From the data collected in the above tables, two more *Tables, X* and *XI* have been compiled. These give the average amount of precipitation per occasion of rainfall associated with winds between SE and SW, as against that with winds lying outside these two directions in winter and transition periods, and the average precipitation with winds between NE and SE as compared with that associated with winds from other directions during the monsoon season.

It will be seen that the average rainfall per occasion associated with SE'ly to SW'ly winds is appreciably greater than that with other winds during the winter and pre-winter periods, while during the monsoon season the average precipitation with NE'ly to SE'ly winds is greater than that with winds from other directions. The post-winter period shows some anomalies, these being mainly due to one occasion of heavy (0·60") rainfall associated with a NE'ly wind at 0·5 Km. and E'ly wind at

3 Kms. on June 27th, 1931, a date which falls too late in the post-winter period, and is expected to be influenced at times by the characteristics of the monsoon season The unusually high values associated with winds of velocity 16 m. p. h or above during the monsoon and post-monsoon periods are also accountable to one occasion of heavy fall in each case.

It will be further seen from *Tables X* and *XI* that, with favourable wind direction, average rainfall per occasion generally increases with the strength of the wind.

6 Although it is realised that the available rainfall data are not sufficiently extensive to give reliable mean values of amount of rainfall, number of occasions of precipitation, etc , at different hours it is thought that the above analysis based on five years' data gives a fairly approximate idea as to the nature of their variations from season to season and in different parts of the day. Further, the characteristics of upper winds on rainy days in different seasons, as revealed by the above study will, in all probability, hold good after a scrutiny of data extending over a larger number of years.

TABLES.

TABLE

Hourly distribution of rainfall amount (total of five years, July 1926 to

—	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13
Months													
January	0.20"	0.27"	0.38"	0.19"	0.26	0.25	0.34	0.28	0.28	0.31	0.27	0.23	0.21"
February	0.53	0.54	0.63	0.58	0.89	0.64	0.54	0.77	[illegible]	0.44	0.47	0.31	0.48
March	0.02		0.09	0.06	0.28	0.40	0.28	0.30	0.08	0.12	0.01	0.15	0.17
April		0.21	0.18	0.08	0.06	0.04	0.01	0.04	0.03	0.02	0.16	0.03	0.07
May			0.03	0.01									
June	0.05	0.02											
July	0.03					0.02	0.06						
August													0.08
September													
October				0.01					0.01	0.03	0.03	0.02	
November	0.01	0.04	0.08	0.06	0.06	0.01		0.02	0.01	0.05	0.06	0.22	0.18
December	0.25	0.28	0.26	0.26	0.24	0.23	0.32	0.22	0.28	0.23	0.20	0.23	0.35
Seasons													
Winter	1.00	1.28	1.54	1.17	1.71	1.55	1.49	1.59	1.19	1.12	1.11	0.95	1.21
Post-winter	0.05	0.02	0.03	0.01	0.02	0.01		0.02	0.02				0.05
Monsoon	0.03					0.02	0.06						0.08
Pre-winter	0.01	0.04	0.06	0.07	0.06	0.10		0.02	0.02	0.08	0.09	0.24	0.18
Year	1.09	1.34	1.63	1.25	1.79	1.68	1.55	1.63	1.23	1.20	1.20	1.19	1.52

T

June 1931) in different months, seasons and in the whole year.

13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Total	Average based on 5 years' data	Normals based on 43 years' records
0 61'	0 56'	0 51	0 49'	0 50'	0 43"	0 28"	0 47"	0 35'	0 22"	0 35"	8 22"	1 64"	1 93"
0 65	0 49	0 67	0 77	0 64	0 60	0 57	0 50	0 40	0 36	0 42	13 43	2 69	1 86
0 25	0 24	0 31	0 34	0 43	0 53	0 34	0 27	0 25	0 24	0 06	5 20	1 04	1 88
	0 03	0 34	0 61	0 19	0 25	0 48	0 46	0 24	0 07	0 02	3 62	0 72	1 03
0 20	0 15	0 03	0 18	0 19						0 03	0 82	0 16	0 37
	0 02	0 01		0 04	0 16	0 05	0 08	0 08	0 04	0 06	0 63	0 13	0 15
0 14	0 28	1 15	0 49	0 51	0 31	0 17	0 11	0 23	0 07	0 02	3 59	0 72	0 63
0 06			0 08		0 02						0 24	0 05	0 46
0 06	0 19	0 01"	0 18	0 01							0 45	0 09	0 07
	0 03	0 02	0 02	0 01							0 018	0 04	0 13
0 20	0 12	0 06		0 04		0 06	0 02			0 02	1 39	0 28	0 32
0 34	0 36	0 53	0 50	0 29	0 25	0 30	0 18	0 16	0 23	0 17	6 66	1 33	0 92
1 85	1 66	2 15	2 66	2 05	2 04	1 97	1 90	1 36	1 12	1 02	36 69	7 34	7 28
0 20	0 19	0 25	0 23	0 23	0 18	0 07	0 06	0 12	0 04	0 09	1 89	0 38	0 86
0 26	0 47	1 16	0 75	0 52	0 33	0 17	0 11	0 23	0 07	0 02	4 28	0 86	1 16
0 20	0 15	0 08	0 02	0 05		0 06	0 02			0 02	1 57	0 31	0 45
2 51	2 47	3 64	3 66	2 85	2 55	2 27	2 09	1 71	1 23	1 15	44 43	8 89	9 75

TABLE

Number of times in which different hours of the day in various seasons were associated

—	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Winter	33 (3)	34 (3)	42 (4)	36 (4)	46 (5)	45 (5)	43 (4)	37 (4)	41 (4)	42 (4)	33 (3)	31 (3)
Post-winter	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)		1 (3)	1 (3)		.	.. .
Monsoon	1 (2)					1 (2)	1 (2)					
Pre-winter	1 (3)	1 (3)	1 (3)	3 (8)	2 (5)	1 (3)		1 (3)	2 (5)	3 (8)	2 (5)	3 (8)

TABLE

Number of times in which different hours of the day in various

—	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Winter	2	4	4	2	4	6	3	3		1	3	3
Post-winter												.
Monsoon												..
Pre-winter							1					1

TABLE

Average amount for each hour of

—	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
Winter .	0·03″	0·03″	0·04″	0·0[illegible]	0·04″	0·03″	0·03	0·04″	0·03″	0·03″	0·03″	0·03″
Post-winter	0·05″	0·02″	0·03″	0·01″	0·02″	0·01″		0·02″	0·02″			
Monsoon .	0·03″		.			0·02″	0·06″		..			
Pre-winter	0·01″	0·04″	0·06″	0·02″	0·03″	0·10″		0·02″	0·02″	0·03″	0·05″	0·08″

II

with rainfall (0·01″ or more) and their percentage frequencies in brackets.

12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Totals.
40	46	52	48	52	48	42	41	37	38	33	37	977
(4)	(5)	(5)	(5)	(5)	(5)	(4)	(4)	(4)	(4)	(3)	(4)	
2	2	4	5	4	2	2	1	2	2	1	2	37
(5)	(5)	(11)	(13)	(11)	(5)	(5)	(3)	(5)	(5)	(3)	(5)	
1	4	6	5	8	8	7	6	3	4	2	1	58
(2)	(7)	(10)	(9)	(14)	(14)	(12)	(10)	(5)	(7)	(3)	(2)	
2	3	3	3	1	2		1	1		.	1	37
(5)	(8)	(8)	(8)	(3)	(5)		(3)	(3)		.	(3)	

III.

seasons were associated with rainfall (0·10″ or more).

12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Totals.
2	6	3	7	7	7	6	6	7	3	2	1	92
.	1	1	1	1	1	1						6
	1	2	1	2	2	1			1			10
1	1	1										5

IV.

precipitation in different seasons

12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24	Totals.
0·03″	0·04″	0·03″	0·04″	0·05″	0·04″	0·05″	0·05″	0·05″	0·04″	0·03″	0·03″	
0·03″	0·10″	0·05″	0·05″	0·06″	0·11″	0·09″	0·07″	0·03″	0·06″	0·04″	0·05″	
0·08″	0·07″	0·08″	0·23″	0·09″	0·07″	0·05″	0·03″	0·04″	0·06″	0·03″	0·02″	
0·09″	0·07″	0·5″	0·02″	0·02″	0·03″	.	0·06″	0·02″		.	.	

TABLE V.

Thunderstorm Frequencies (July 1926 to June 1931).

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
..	..	8	7	6	5	25	8	3	..	..	1

TABLE VI.

Percentage frequencies of winds at 0·5 Km. above ground over Quetta.

—		N	NE	E.	SE.	S	SW	W.	NW.
Winter	Normal	8	2	1	6	30	6	18	32
	Rainy day	1	1		7	61	20	9	4
Post-winter	Normal	6	1		4	26	10	24	30
	Rainy day	6	6	.	13	57	6	13	..
Monsoon	Normal	8	1	1	10	31	14	18	18
	Rainy day	9	4	26	17	34	4	.	4
Pre-winter	Normal	17	3	.	4	14	5	17	40
	Rainy day	.	..		17	17	33	17	17

TABLE VII.

Percentage frequencies of winds at 3 Kms. above sea level over Quetta.

—		N	NE	E	SE.	S.	SW	W.	NW.
Winter	Normal	5		..	1	7	18	22	46
	Rainy day	1		.	1	20	42	28	6
Post-winter	Normal	7	.	.	1	4	10	24	54
	Rainy day	.	.	6	6	6	38	31	3
Monsoon	Normal	6	3	2	1	3	7	31	49
	Rainy day	30	34	13	..	..	9	9	4
Pre-winter	Normal	17	1	1	..	4	7	21	49
	Rainy day	..	..	..	..	..	50	50	..

Table VIII.

Distribution of occasions and amount of rainfall according to winds at 0·5 Km. above ground.

—		N.	NE.	E.	SE.	S.	SW.	W.	NW.
Winter Period.—									
Irrespective of velocities	(a)	1	1	3	11	63	24	19	9
	(b) . .	0·17"	0·02"	0·55"	0·93"	12·65"	3·56"	1·44"	0·46"
Velocity=or> 8 m.p.h.	(a) . .		.	1	7	50	14	11	4
	(b)	.		0·04"	0·66"	9·95"	2·16"	0·92"	0·12"
Velocity= or>16 m.p.h	(a)				4	26	7	4	1
	(b) ..	..			0·30"	5·70"	1·22"	0·32"	0·01"
Post-winter Period —									
Irrespective of velocities	(a)	1	1		2	11		1	1
	(b)	0·19"	0·60"		0·20"	0·72"		0·23'	0·03"
Velocity=or>8 m p.h	(a)				1	9	.	1	1
	(b)				0·12"	0·65"		0·23"	0·03"
Velocity=or>16 m p.h.	(a) .					4		1	..
	(b)					0·12"	--	0·23"	..
Monsoon Period—									
Irrespective of velocities	(a) . .	3	1	6	4	9	3	2	3
	(b) . ..	0·12"	0·01"	1·91"	0·25"	1·00"	0·45"	0·30"	0·23"
Velocity=or>8 m. p.h.	(a) . ..	1	1	5	2	5	2	1	1
	(b) . .	0·02"	0·01"	1·76"	0·15"	0·61"	0·17"	0·04"	0·14"
Velocity=or>16 m p.h.	(a) . .	1		1	.	1	.	1	..
	(b) . ..	0·02"		1·26"		0·18"	.	0·04"	..
Pre-winter Period.—									
Irrespective of velocities	(a)	..	..	..	..	2	2	2	2
	(b)	..	.	..	.	0·93"	0·16"	0·20"	0·19"
Velocity=or>8 m.p.h.	(a)	..	..	..	..	1	2	1	..
	(b)	.	..	..	..	0·74"	0·16"	0·05"	..
Velocity=or> 16 m.p.h.	(a)	..	.	..	..	1	..	.	..
	(b) . ..	..	..	..	..	0·74"	..	..	..

(a) Number of occasions ; (b) Total Rainfall.

TABLE IX.

Distribution of occasions and amount of rainfall according to winds at 3 Kms. above Sea level over Quetta.

———		N	NE	E.	SE.	S	SW.	W	NW.
Winter Period—									
Irrespective of velocities	(a) ..	2	.	.	1	26	44	37	7
	(b) .	0 09"	.	.	0 02"	3·60"	9 42"	3 92"	1·00"
Velocity=or>8 m.p.h.	(a) ..	1	..	..	1	24	42	34	5
	(b) ..	0·06"	.		0·02"	3·18"	9 22"	3 73"	0·77"
Velocity=or>16 m.p.h.	(a) .				1	15	30	24	3
	(b) ..	..	.	.	0·02"	2 45"	7 49"	2·52"	0·06"
Post-winter Period—									
Irrespective of velocities	(a) ..		.	1	1	3	5	6	1
	(b)	.		0 60"	0 06"	0 24"	0 28"	0·60"	0·19"
Velocity=or>8 m.p.h	(a) .	.		1		3	4	3	..
	(b)			0 60'		0 24"	0 17"	0 42"	..
Velocity=or>16 m.p h	(a)					3	1	1	.
	(b)	.		.		0 24"	0 12"	0 23"	
Monsoon Period—									
Irrespective of velocities	(a)	6	9	6	3	1	1	3	2
	(b) .	0 47"	0 78"	1 83"	0 43"	0 14"	0 08"	0 23"	0·31"
Velocity=or >8 m p h	(a)	1	8	4	2			3	2
	(b)	0 22"	0 63"	1 55"	0 25"			0 22"	0·31"
Velocity=or >16 m p h	(a)	2	1	2				1	
	(b)	0 04"	0 06"	1 34"				0 04"	..
Pre-winter Period—									
Irrespective of velocities	(a) .			.	..	..	5	3	
	(b) .	.			..	..	0 97"	0·41"	
Velocity= or > 8 m.p h.	(a) ..	.		.	..	..	3	3	
	(b) ..	..	..	..	..	..	0·92"	0·41"	..
Velocity= or>16 m.p.h.	(a) ..	..	..	..	..	..	1	1	.
	(b) .	..	..	..	..	..	0·74"	0·17"	..

(a) Number of occasions; (b) Total Rainfall.

TABLE X.

Amount of rainfall per occasion associated with winds at 0·5 Km. above Quetta.

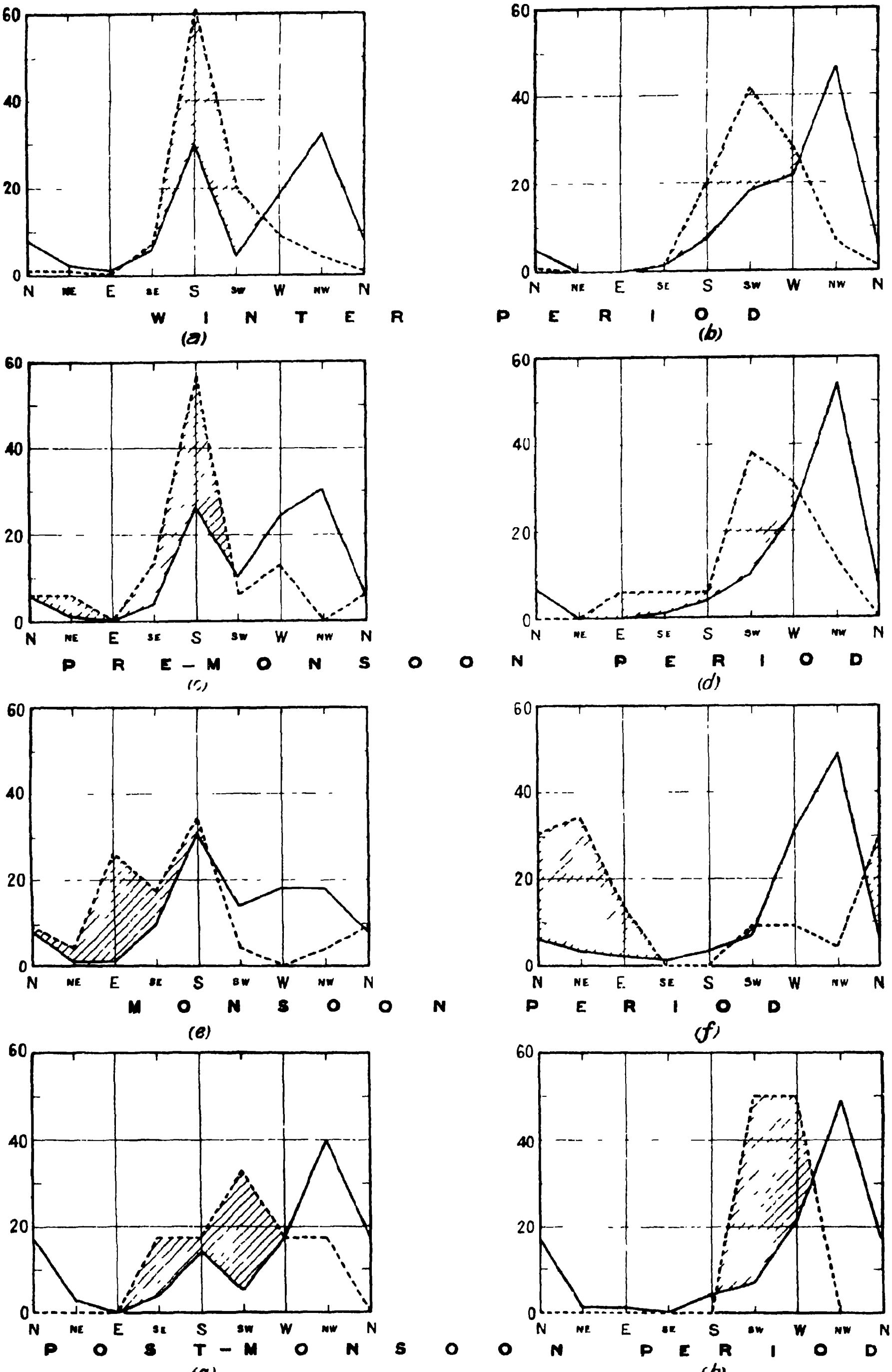
——	With SE to SW'ly winds.	With other winds.
Winter period—		
Irrespective of velocities	0·18"	0·08"
Velocity = or > 8 m p h.	0·18"	0·07"
Velocity = or > 16 m p.h	0·19"	0·07"
Post-winter period—		
Irrespective of velocities	0·07"	0·26"
Velocity = or > 8 m p h.	0 08"	0·13"
Velocity =or > 16 m p h.	0 03"	0·23"
Pre-winter period—		
Irrespective of velocities	0·27"	0·17"
Velocity = or > 8 m.p.h	0 30"	0 05"
Velocity = or > 16 m p h	0·74"	..
	With NE to SE'ly winds.	With other winds.
Monsoon period —		
Irrespective of velocities	0 20"	0·11"
Velocity = or > 8 m p.h.	0 24"	0·10"
Velocity = or > 16 m p h.	1 26"	0·08"

TABLE XI.

Amount of rainfall per occasion associated with winds at 3 Kms. above Sea level over Quetta.

——	With SE to SW'ly winds.	With other winds.
Winter period —		
Irrespective of velocities . . .	0 18"	0 11"
Velocity = or > 8 m p h	0 18"	0 11"
Velocity = or >16 m p h .	0 22"	0·09"
Post-winter period—		
Irrespective of velocities . . .	0 06"	0·17"
Velocity = or > 8 m p h .	0 06"	0·25"
Velocity = or > 16 m p h.	0 09"	0·23"
Pre-winter period—		
Irrespective of velocities	0 19"	0·14"
Velocity = or > 8 m p h	0·31"	0·14"
Velocity = or > 16 m p h	0·74"	0·17"
	With NE to SE'ly winds.	With other winds.
Monsoon period—		
Irrespective of velocities	0·17"	0·09"
Velocity = or > 8 m.p.h.	0·17"	0·08"
Velocity = or > 16 m.p.h.	0·47"	0·03"

M11DGOb—360—25-11-32—GIPS



AT 0·5KM ABOVE QUETTA. AT 3KMS ABOVE SEA LEVEL.

(NORMAL —— RAINY–DAY -----)

PERCENTAGE FREQUENCIES OF UPPER WINDS AT QUETTA

FIG. 1.

ERRATA.

In curves *c, d, g* and *h* *for* " pre-monsoon and post-monsoon " *read* " post-winter and pre-winter " respectively.

INDIA

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Tables extending Walker's Criteria and for finding the Chance of Success of a Forecast

BY

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TABLES EXTENDING WALKER'S CRITERIA AND FOR FINDING THE CHANCE OF SUCCESS OF A FORECAST

BY

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(Received on 1st March 1932)

Abstract.—In 1914 G. T. Walker published tables for picking out significant correlation coefficients or periodicities from among a number of them. According to him those values are significant which have a random chance of less than 50 per cent. for occurring. In this paper tables have been given for selecting those values for the occurrence of which by random there is a chance of less than 5 per cent. Tables have also been given for calculating the chance of success of a forecast made using a regression formula.

Introduction.—In 1914 G. T. Walker (1) published tables extending Pearson and Filon's (2) formula for the error of a correlation coefficient so as to make it applicable for finding the significance or otherwise of a C. C. from among a number of them. In the same paper he gave tables extending Schuster's criterion (3) to determine which of a number of calculated periodicities can be considered real. The way in which these tables are to be used will be found in (1), (5) and (12).

Two objections may be raised against the first set of tables. In the first place, Pearson and Filon's formula (2) for the error of a C. C. is approximate and does not hold when the number of data used for correlating is small. This objection may, however, be overcome by using Fisher's "z" (6) instead of r. The exact method will be found on page 74 of (7).

The second objection appears to have been first raised against the second set of tables, referred to above, by Dinsmore Alter (8) and is applicable to the first set of tables as well. The objection may be briefly stated thus.

Walker's tables (1) were constructed to give the *probable* value of the highest C. C. or of the highest intensity of a periodicity from among a number of random ones. This means that the chance of getting values not less than this is even (*i.e.*, 50 per cent.). Now, as Dinsmore Alter (8) has pointed out, many would consider this a somewhat lenient test of significance. One would therefore like to have a more stringent test.

Tables extending Walker's criteria.—To be quite sure that a result is significant some persons have laid down that it must not be less than four times its standard error, see for example page 38 of (9). This appears to be a very strict standard, for, on the assumption of the normal law for errors, the chance of getting such a high value by pure chance is about 6 in 100,000 or less than 0·01 per cent.

A much less stringent test is that which appears to have been first recommended by R. A. Fisher and is his 5 per cent. test According to this test, all values, for obtaining which there is a random chance of not more than 5 per cent, will be considered significant. This appears to have been more or less accepted now-a-days, see *e.g.* (10). It was therefore thought worth while to recalculate Walker's tables on the basis of this limit of significance

The method of calculating the tables was the same as that suggested by Walker (1), except that 0·95 was used instead of ½ for the chance As it was thought advisable to combine Walker's and the present tables into one, the probable value of a single random C. C. or of the intensity of an accidental periodicity was taken as the unit in computing the new tables. These tablies are given as *Table I* at the end.

Method of using Table I.—The tables (A and A_1) will be found useful in an investigation like the following.—

Example (1).—With a view to obtaining a forecasting formula for the rainfall of Siam, the latter was correlated with some data at 20 different meteorological centres. Which of these coefficients may be considered significant, if the number of elements for each be 25 ?

Using Fisher's "z", mentioned above, we get

$$\text{Probable error of } z = \pm \frac{0\cdot 674}{\sqrt{n\text{-}3}}$$

In our example, $n = 25$.

Probable error of $z = \pm\, 0\cdot 144$.

(1) If we are satisfied with Walker's limit of significance, we must use the value of A in Table I corresponding to $M = 20$ In this case,

$$\text{" Probable " highest value of } z \text{ due to pure chance} = 0\cdot 144 \times 3\cdot 14.$$
$$= 0\cdot 452.$$

The corresponding value of r may be obtained from the tables given on page 177 of (6) and is 0·42. Hence, on Walker's limit of significance, all values of the C. C. above 0·42 are to be considered significant

(2) For Fisher's limit of significance we must use the value of A_1 in *Table I* corresponding to $M = 20$. We have—

"5 per cent. chance" highest value of z due to accident $= 0\cdot 144 \times 4\cdot 48 = 0\cdot 645$.

The value of r corresponding to this is 0·57.

Hence in this case no value of a C. C. less than 0·57 will be considered significant.

An equally important question is. "Having selected a C. C. as significant what are the limits between which its true value is likely to lie ?" Suppose the value of a selected C. C. is 0·66 and its probable error is $\pm\, 0\cdot 12$, then $0\cdot 66 - 0\cdot 12$ and $0\cdot 66 + 0\cdot 12$ (*i.e.*, 0·54 and 0·78) may be called the "probable" limits within which the true value lies. That is to say, there is only a chance of 25 per cent. that the true value is less than 0·54 and 25 per cent chance that the true value is more than 0·78, *i.e.*, we are 50 per cent. sure that the true value lies between 0·54 and 0·78. Similarly if there be only a 2½ per cent. chance that the true value of another C. C. is less than 0·23 and 2½ per cent. chance that it is above 0·88, *i.e.*, if we are 95 per cent. confident that the true value lies between 0·23 and 0·88, we may

call these limits the "95 per cent" limits. The "probable" and the "95 per cent" limits of a selected C C. can be found as shown in the following example.

Example (2) Out of 20 random C. Cs., for each of which $n = 30$, a selected C. C. has a value 0·51 To find its "probable" and "95 per cent." limits.

"z" corresponding to $r = 0{\cdot}51$ is $0{\cdot}562$

$$\text{The probable error of a single random } z = \pm \frac{0{\cdot}674}{\sqrt{27}}$$
$$= \pm 0{\cdot}130.$$

(*i*) To find the "probable" limits we multiply $\pm 0{\cdot}130$ by 3·14, which is the value of A in Table I corresponding to $M = 20$, and thus get $\pm 0{\cdot}408$.

Hence the "probable" limits of z are $0{\cdot}562 \pm 0{\cdot}408$. The corresponding values of r are: $r_1 = 0{\cdot}15$, and $r_2 = 0{\cdot}75$.

∴ The "probable" limits of the C C 0·51 are 0·15 and 0·75

(*ii*) For the "95 per cent." limits we use the value of A_1 corresponding to $M = 20$ We get $\pm 0{\cdot}13 \quad 4{\cdot}48 = \pm 0{\cdot}582$.

The "95 per cent." limits of z are $0{\cdot}562 \pm 0{\cdot}582$. The corresponding values of r are: $r_1 = -0{\cdot}02$ and $r_2 = 0{\cdot}82$.

∴ The "95 per cent." limits are —0·02 and 0·82.

Incidentally we may also see that 0·51 is significant according to Walker's criterion since the "probable" limits have the same sign, while according to the "5 per cent." test it is not significant, as the "95 per cent." limits have opposite signs. Even the "probable" limits are so wide apart that we cannot attach much importance to the value 0·51

With regard to the second set of tables, B, given by Walker in the same Memoir (1) for finding the significance of harmonic periods a further objection may be raised. Schuster's result, which has been used by Walker, namely, that the probability that owing to random chance the intensity (*i.e.*, square of the amplitude) of a period will exceed h times the average intensity is e^{-h} is strictly true if the average intensity is obtained from a number of random samples from the same population. But in a large number of cases there is only one sample and we cannot assume that the average intensity obtained from that sample is the true average. Hence Walker's tables need correction.

The correct value of the required chance has already been given by Fisher (13). According to Fisher's investigation the probability that the largest of the n intensities in a periodogram should exceed g by mere chance is

$$P = n\,(1-g)^{n-1} - \ldots\ldots\ldots + (-1)^{k-1} \frac{n\,!}{k\,!\,(n-k)\,!}\,(1-kg)^{n-1}, \ldots\ldots \quad (1)$$

where k is the largest integer less than $\frac{1}{g}$ and g is any intensity expressed as a fraction of the total intensities, *i.e.*, $= \dfrac{x}{x_1 + x_2 + \ldots + x_n}$ where

$x_1, x_2, \ldots\ldots\ldots, x_n$ are the n intensities.

In the same paper (13) Fisher has also given the 5 per cent. values of g for values of n from 5 to 50, but the unit he has used is different from that of Walker. In

the present paper a few of Walker's values, B, have been recalculated using the accurate formula (1) above and have been given as B in *Table I*. Fisher's 5 per cent. values of g have been converted to Walker's unit, which is the average intensity, and are given under B_1 in *Table I*. Some other values of B_1 have also been calculated and given in the same table. The method of using these tables is so straight-forward that it is not considered necessary to give any illustration.

Tables for calculating the chance of success of a forecast.—The seasonal forecasts issued by this Department in the past often contained the word "normal" and other terms that may have conveyed different ideas to different people. In 1930 Dr. C. W. B. Normand, the Director General of Observatories, decided that an effort should be made to avoid ambiguity by a more definite statement of limits, such as "Rainfall will be below 80 per cent of the average" or "Rainfall will lie between 70 and 90 per cent. of the average". This suggestion could not be taken up until the forecast formulæ were brought up to-date. In January 1931, this piece of work was over and the suggestion was given effect to in the very next forecasts issued in June 1931 A similar suggestion in a slightly extended form has also been made independently by H. M. Treloar ([11]).

In order to find out quickly the chance of success of a forecast or to determine the forecast that will have a given chance of success, tables were calculated at the instance of Dr. Normand. As it is believed that these tables will be found useful by forecasters elsewhere, they are given at the end as *Table II*.

Method of calculating the tables.—Let x be the departure from normal of an element to be forecast, y the departure calculated from a regression formula having a C. C. equal to r. We can write

$$x = y + t,$$

where t is a quantity which is statistically independent of y. x, of course, is not known when the forecast is made.

Suppose the forecast issued is that the departure from normal will not be less than c, then it is easy to see that the chance of success for this forecast is the same as that for t not having a value less than $c - y$. This chance can be calculated from the usual tables* on the assumption that t obeys the normal law and remembering that $\sigma_t = \sigma_x \sqrt{1-r^2}$. As we can compress the tables very much by using σ_x as the unit, *Table II* was calculated in this manner. Theoretically the chance of success is given by

$$p = \frac{1}{\sqrt{2\pi}} \int_{\frac{c-y}{\sigma_x\sqrt{1-r^2}}}^{\infty} e^{\frac{t^2}{2}} \, dt$$

Method of using Table II.—In the above illustration, the chance of success for the forecast is the value of p in *Table II* corresponding to

$$a = \frac{c-y}{\sigma_x} \text{ and } r.$$

Example (*3*).—For the Peninsula (June-September) rainfall formula, $r = 0\cdot69$. If $y = +3\cdot30''$, what is the chance that the actual will not fall below 95 per cent. of the normal ?

For this formula $\sigma_x = 5\cdot3''$ and the normal is $34\cdot1''$.

* Tables for Statisticians and Biometricians edited by Karl Pearson and published by the Cambridge University Press.

$\therefore c = -\frac{1}{20} \times 34 \cdot 1 = -1 \cdot 71$ and consequently $a = -\frac{1 \cdot 71 + 3 \cdot 30}{5 \cdot 3} = -0 \cdot 95.$

Using the table for $r = 0 \cdot 7$ (nearest to $\cdot 69$) we see that the required chance of success is $p = 0 \cdot 91$ (by interpolation).

Example (4). Suppose in the above example, the forecast had been " Rainfall will be above 95 per cent. of the average but not exceed it by more than 10 per cent.", the chance of success of this forecast can be calculated as follows :—

The chance that the rainfall will not fall below 95 per cent. of the normal is 0·91 (as calculated above). Similarly we can find that the chance that the rainfall will exceed the normal by 10 per cent., *i.e.*, will not fall below 110 per cent. of the normal, is 0·50

$\therefore$ The chance of success of the forecast $= 0 \cdot 91 - 0 \cdot 50$
$= 0 \cdot 41.$

It may be noted that no values have been given corresponding to r less than 0·4, excepting 0·0. This is because it is believed that no one uses a formula which has a C. C. less than 0·4 for forecasting purposes. The values corresponding to $r = 0 \cdot 0$ have, however, been given to enable the forecaster to see what the chances of success the same forecast would have had if it had been made at random, in order that he might consider whether it was worth while giving that forecast. In the previous example (3), it is easily seen from the tables that the chance of success of the same forecast, if made at random, is only 0·66 and is much less than that of the same forecast given on the strength of the forecasting formula. Hence few would disagree with the issuing of the forecast under these conditions.

In conclusion, we wish to thank the Director General of Observatories, Poona, for having kindly permitted us to make use of the calculations carried out in the statistical branch under him

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TABLE I.

A, A_1 and B, B_1, are the ratios of the probable and the 5 per cent. value of the greatest of M accidental correlation co-efficients and intensities of periodicities, respectively, to the probable value of a single one.

M	C. C.'s		Periodicities.		M	C. C.'s		Periodicities.	
	A (50 %).	A_1 (5 %).	B (50 %)	B_1 (5 %).		A (50%).	A_1 (5%).	B (50%).	P_1 (5 %)
2	1 56	3 32	1·50	1 95	30	3·37	4·66	3·83	5 [illegible]
3	1 87	3 55	1 78	2 61	32	3 41	4 69	3 87	6·02
4	2 09	3 69	2 00	3 07	34	3·44	4·71	3 93	6·09
5	2 25	3 81	2 18	3 42	36	3 47	4 73	3 99	6·16
6	2 38	3 90	2 34	3 70	38	3 51	4 76	4 04	6·27
7	2·48	3 98	2 37	3 93	40	3 53	4 78	4 08	6 30
8	2 57	4 05	2 59	4 13	45	3·60	4 83	4 20	6 44
9	2 65	4 11	2 69	4 30	50	3 65	4 88	4 31	6·57
10	2 72	4 15	2 79	4 45	55	3 70	4 92	4·39	6·69
12	2 83	4·24	2·95	4 59	60	3 75	4 96	4 48	6·79
14	2·93	4 32	3 10	4·92	65	3 79	4 99	4 56	6·88
16	3 00	4 38	3·20	5 11	70	3 83	5 01	4 63	6 97
18	3·08	4·44	3·31	5 27	75	3 86	5·04	4·70	7 05
20	3·14	4 48	3 42	5 41	80	3 89	5 06	4·76	7·12
22	3·20	4·52	3·51	5 54	85	3 92	5·09	4·82	7·19
24	3·25	4·55	3 60	5·65	90	3 95	5·11	4·88	7·25
26	3·29	4·59	3·67	5·75	95	3·98	5·13	4·93	7·32
28	3·34	4·63	3·75	5·85	100	4·01	5·15	4· 8	7·38

TABLE I—*contd.*

A, A_1 are the ratios of the probable and the 5 per cent. value of the greatest of M accidental correlation co-efficients, to the probable value of a single one.

M.	C. C.'s. A (50%).	C. C.'s. A_1 (5 %).	M	C. C.'s. A (50 %).	C. C.'s. A_1 (5 %).
110	4·05	5·19	380	4·62	5·67
120	4·09	5·22	400	4·65	5·69
130	4·13	5·25	420	4·67	5·71
140	4·17	5·28	440	4·69	5·73
150	4·20	5·31	460	4·70	5·74
160	4·23	5·34	480	4·72	5·76
170	4·26	5·37	500	4·74	5·79
180	4·29	5·39	550	4·78	5·82
190	4·31	5·41	600	4·82	5·84
200	4·33	5·43	650	4·85	5·86
220	4·38	5·45	700	4·88	5·92
240	4·42	5·47	750	4·91	5·93
260	4·45	5·51	800	4·94	5·94
280	4·49	5·55	850	4·96	5·96
300	4·52	5·57	900	4·99	5·98
320	4·55	5·59	950	5·01	6·00
340	4·57	5·62	1000	5·03	6·01
360	4·60	5·65			

TABLE II.

Chance that the unpredictable portion (in terms of σ_x) of the element forecast does not fall below '*a*' when *r* is equal to :

A	*0*	·4	·45	·5	·55	·6	·65	·7	·75	·8	·85	·9	·95
—1·5	·93	·95	·95	·96	·96	·97	98	·98	99	·99	1 00	1·00	1·00
—1·4	·92	94	·94	·95	·95	·96	·97	·98	98	99	1·00	1·00	1·00
—1·3	·90	·92	·93	·93	·94	95	96	·97	·98	·98	·9'	1·00	1·00
—1·2	·88	·90	·91	·92	·93	·93	94	95	·97	98	99	1·00	1 00
—1·1	·86	·88	·89	·90	·91	·91	93	·94	·95	97	98	·99	1·00
—1·0	·84	·86	·87	87	88	89	91	·92	94	·95	97	99	1 00
—0·9	·82	·84	·84	·85	·86	·87	88	90	92	93	96	·98	1·00
—0·8	·79	·81	·82	·82	·83	·84	85	·87	89	·91	94	·97	·99
—0·7	·76	78	78	79	80	81	82	·84	86	88	91	·95	·99
—0·6	·73	·74	·75	·75	·76	·77	·79	80	82	·84	87	91	·97
—0·5	·69	·71	·71	·72	·73	·74	75	·76	·78	80	·83	·87	·95
—0·4	·66	·67	·67	·68	·68	·69	·70	·71	·73	75	·78	·82	·90
—0·3	·62	·63	·63	·64	·64	·64	·65	·66	·68	·69	·72	·75	·83
—0·2	·58	·59	·59	·59	·59	·60	·60	·61	·62	·63	·65	·68	·74
—0·1	·54	·54	·54	·55	·55	·55	·55	·56	·56	·57	·58	·59	·63
0	·50	·50	·50	·50	·50	·50	·50	·50	·50	·50	·50	·50	·50

TABLE II—*contd.*

Chance that the unpredictable portion (in terms of σx) of the element forecast does not fall below "*a*" when *r* is equal to :

A	*0*	·4	·45	·5	·55	·6	·65	·7	·75	·8	·85	·9	·95
0	50	·50	·50	50	50	50	50	·50	·50	·50	·50	·50	·50
+0·1	46	46	·46	·45	45	·45	·45	·44	·44	·43	·42	·41	·37
+0 2	·42	·41	·41	41	·41	40	40	39	38	37	·35	·32	·26
+0 3	·38	37	37	36	36	·36	35	34	32	·31	·28	·25	·17
+0 4	34	33	33	32	32	·31	30	·29	27	25	·22	·18	·10
+0·5	31	29	·29	28	·27	26	25	·24	22	20	·17	·13	·05
+0 6	27	·26	25	25	24	23	21	20	18	·16	·13	·09	·03
+0 7	·24	·22	·22	·21	20	·19	18	16	14	·12	·09	05	·01
+0 8	21	19	18	18	17	16	15	13	·11	09	06	·03	·01
+0 9	·18	16	16	15	14	13	12	10	08	07	·04	·02	00
+1 0	·16	14	13	13	12	11	09	08	06	05	·03	01	·00
+1 1	14	12	11	10	09	09	·07	·06	05	·03	·02	·01	·00
+1·2	·12	·10	·09	08	·07	07	06	·05	03	·02	01	·00	·00
+1·3	·10	08	07	07	·06	·05	·04	·03	02	·02	·01	·00	·00
+1·4	·08	·06	·06	·05	·05	·04	03	·02	·02	·01	·00	·00	·00
+1·5	·07	·05	·05	·04	·04	·03	·02	·02	·01	·01	·00	·00	·00

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On some Characteristics of the Tropopause and Upper Troposphere over North-West India

BY

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ON SOME CHARACTERISTICS OF THE TROPOPAUSE AND UPPER TROPOSPHERE OVER NORTH-WEST INDIA

BY

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Abstract.—The chief features of three principal types of tropopause over North-West India, based on sounding balloon ascents at Agra, have been discussed. Mention has been made of a characteristic region of small lapse rate or inversion commonly found between 11 5—14 gkms

With the aid of sounding balloon records and stream-lines of upper air, the physical features of an anti-cyclone in Upper India in December 1930 have been discussed in the light of the theory of advection of air-mass as developed by Rossby. Changes in temperature at different levels for a few successive days during the period of existence of the anti-cyclone have been calculated with the aid of Rossby's theory.

1. In the records of meteorographs let off with sounding balloons from the Upper Air Observatory at Agra, three principal types of transition from troposphere to stratosphere are found. Mention has already been made of the characteristics of these types, called *A*, *B* and *C*[1]. The mean heights and temperatures of these three types of tropopause as obtained from data for the period April 1926—December 1930 are given in *Table 1.*

Table 1.

Type.	Hc. (Height in gkms)	Tc (Temperature in °A).	N. (No. of observations).	Standard Deviation.	
				Hc (gkms).	Tc (°A)
A	16·53	195·5	59	·80	5·1
B	15·75	197·2	37	·69	4·4
C	16·09	197·3	26	1·10	5·1

The percentage frequency of occurrence of the three types in different months of the year is shown in *Table 2*.

TABLE 2.

Type.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
A ..	10 2	6·8	6·8	10·2	6·8	3·4	6·8	8·5	11·9	5·1	15·2	8·5
B ..	8·1	5·4	8 1	13·5	5·4	5·4	0	8·1	10 8	13·5	13·5	8·1
C ..	0	3·8	11 5	11·5	15·4	15·4	0	7·7	7·7	11·5	11·5	3·8

During July, only type *A* is met with and so far no record with tropopause of the type *B* or *C* has been obtained in this month. Owing to the prevailing directions of upper winds in North-West India, the regions where the instruments descend are far removed from human habitation, and hence the data so far collected for July are meagre.

The individual values of H_c and T_c for winter, from December to March, for summer, from April to June, and for rainy season, from July to September, were grouped together for different ranges of pressure at mean sea level at the times of ascent. No relation between H_c, T_c and pressure at mean sea level as given by Gold[2] could be obtained for summer and rainy seasons, but for winter a relation between H_c and pressure, similar to that of Gold, is noticeable. This is shown in *Fig. 1* and the data from which the graph is drawn are given in *Table 3*.

TABLE 3.

Period.	Pressure (mb).	>1015	1015-1013.	1013-1011.	1011-1009.	1009-1007.	1007-1005.	1005-1003.	1003-1001.
	Hc (gkm) ..	16·71	16·34	16·62	16·05	15·91	15·76	..	15·48
Winter	Tc (190°A+) ..	8·0	10·0	8 9	8·7	12 4	5·9	..	13·0
	Mean P (mb) ..	1016 9	1014·1	1012 9	1010 1	1008 3	1006·7	..	1003·0
No. of observations (Total No. 34.)	.	7	6	7	6	4	3	..	1

The height and temperature of tropopause have been fixed according to the criteria accepted for *A*, *B* and *C*.

From *Table 3* it is seen that no definite conclusion regarding a similar relation between *T* and pressure can be drawn.

The above relation may probably be taken in support of the view that in winter the upper atmosphere of North-West India is controlled by the pressure gradients of temperate latitudes.

The data now available confirm the sequence of monthly variation of the mean temperature of tropopause[3] but no *appreciable* seasonal variation of the height of tropopause is noticed.

During the period November to May, a region of very small positive, zero, or negative lapse rate is frequently found below the usual level of tropopause, as shown in

Fig. 2. Sometimes this characteristic is found at the cirrus level, but generally above it. Occasionally a short or a long region of inversion or an isothermal region is found to exist just below the tropopause and in continuity with it. A preliminary examination shows that these may originate from different causes. The physical aspects of this characteristic will be discussed in a future communication.

The range of height at which this type of discontinuity is found to exist is 9—17 gkms, but the frequent range is 11·5—14 gkms. The difference of temperature between the upper and lower levels of these regions varies from —1°C to + 6·8°C. The shortest and longest regions over which such a discontinuity in the temperature-height diagrams of sounding balloon records has yet been found to extend are 0·2 km. and 3·8 kms. respectively.

2. Exner[4] has attempted to solve in a general way the effect of variations of pressure in the stratosphere on the vertical distribution of temperature and pressure in the troposphere. Rossby[5] has calculated under certain simplified assumptions the effect of an arbitrary advection current upon the vertical distribution of temperature and pressure in a column of air. According to his theory, a quantity π at a level Z can be estimated from any pair of consecutive soundings at a station. It gives a direct measure of the difference of weight between the displacing and displaced air-masses. As the calculations have been made use of in the following section for the study of the characteristics of an anti-cyclone, it is necessary to state here the main results of Rossby's theory and the assumptions on which it is based. For calculating π at any level, the following equation has been derived :—

$$\pi = \delta_l p + \frac{C_v}{C_p} \cdot \frac{mg}{R} \cdot p^{\frac{R}{mC_p T}} \int_0^z \delta_l p \cdot p^{-\frac{R}{mC_p}} dz. \quad . \quad . \quad . \quad . \quad (1)$$

where z is altitude above mean sea level, and $\delta_l p$ the local variation of pressure. The other symbols for dry air have their usual meaning as in the theory of heat.

If f be a characteristic property of air, $\delta_l f$ the local variation of f, is connected with $\delta_i f$, the variation of f in an individual layer of air, by the relation

$$\delta_i f = \delta_l f - \frac{df}{dz} \delta z \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If the potential temperature θ is defined by $\theta = \dfrac{T}{p^{R/mC_p}} \cdot P^{\frac{R}{mC_p}}$

P being the standard pressure, (1) simplifies to

$$\pi = \delta_l p + 2 \cdot 43 . 10^{-4} \frac{1}{\theta} \int_0^z \delta_l p \frac{\theta}{T} dz. \quad . \quad . \quad . \quad . \quad (3)$$

The numerical values $\dfrac{R}{mC_p} = 0 \cdot 288$ and $\dfrac{C_v}{C_p} \dfrac{mg}{R} = 2 \cdot 43 \cdot 10^{-4}$ have been used to obtain (3).

In the evaluation of sounding balloon data p is estimated in millibars, and if $\delta_l p$, which is usually small, is obtained from the tabulated values of pressure at different levels from any two consecutive sounding balloon ascents, the possible magnitude of error in $\delta_l p$ is rather large.

Hence it has been calculated from $\dfrac{\delta_l p}{p} = \dfrac{\delta_l p_0}{p_0} + \dfrac{mg}{R} \displaystyle\int_0^z \frac{\delta_l T}{T^2} dz \quad . \ (4)$

$\delta_t T$ being the local variation of temperature at any particular level. The usual hypsometric formula $p = p_o e^{-\frac{mg}{R}\int_0^z \frac{dz}{T}}$ . . . . (5)

gives (4) after variation.

Though $\delta_t T$ is obtained from the tabulated data of sounding balloon ascents the value of $\delta_t p$ depends on the integral $\int_0^z \frac{\delta_t T}{T^2} dz$ and not on $\delta_t T$ at a single level and thus the error is minimised.

It is also possible to calculate at any altitude the variations of temperature in the intervening period between two consecutive soundings, and the relation obtained by Rossby is

$$\delta_t T = \frac{R}{mg} \cdot \frac{T^2}{p} \cdot \frac{d\pi}{dz} + \frac{R}{mC_p} \cdot \frac{T}{p} \cdot \pi + \frac{dT}{dz} \cdot \frac{C_v}{C_p} \cdot \int_0^z \frac{\pi}{p} dz \quad . \quad . \quad (6)$$

The first term of (6) gives the change in temperature in a layer dz at z due to advection, the second the change in the same layer due to adiabatic compression or rarefaction due to increase or decrease of pressure above, and the third the local change due to vertical displacement as a result of advection.

The assumptions of the theory are as follows :—

1. Advection takes place under adiabatic conditions, the phenomena of radiation, conduction of heat, turbulence, condensation, and evaporation not being taken into account.

2. No allowance is made for lateral expansion or contraction of an air column under the influence of advection of air-masses.

3. Advection at one level is supposed to be unaffected by simultaneous advection at other levels.

4. Due to advection, a layer of thickness dz is displaced by another of the same thickness.

It is thus seen that the theory is only applicable to a limited class of advection phenomena, and the object of the following section is to examine how far the observed facts, as observed in an anti-cyclone, can be accounted for by it.

It should be emphasised here that, under certain conditions, the theory leads to estimates of temperature at some heights which are not in agreement with observed values. For example, at level z the air-mass may be replaced by advection by a slightly cooler mass of air. But for the same reason the increase of pressure above causes a rise in temperature at z by adiabatic compression. This may exceed the cooling due to advection, and hence a rise in temperature, instead of a fall, would be registered by a balloon meteorograph.

3. The anticyclone of 19th—26th December 1930 over Upper India.

The data for temperature, pressure and humidity obtained at Agra on 19th, 22nd, 23rd and 25th December 1930 are collected in *Table 4*. Unfortunately there have been breaks in some of the records ; thus data for some heights are wanting.

TABLE 4.

Z = Height in geodynamic kilometers.

P = Pressure in mbs.

T = Temperature in absolute degrees.

H = Humidity per cent.

Z.	19th December 1930 Ascent at 16h. 11m. I. S. T.			22nd December 1930 Ascent at 16h 1m I. S. T.			23rd December 1930 Ascent at 16h 5m I. S. T.			25th December 1930 Ascent at 17h. 1m. I. S. T.		
	P.	T	H.	P	T	H	P.	T	H.	P	T.	H.
0·17	997	295	33	996	295	19	997	293	22	998	290	39
1	902	288	52	901	287	24	903	287	33	902	289	45
2	799	282	47	798	285	13	800	287	19	801	287	33
3	705	275	35	706	282	8	706	282	16	708	281	29
4	621	271	35	624	275	13	624	279	14	625	275	27
5	546	266	36	548	271	14	550	271	14	550	269	25
6	478	260	35	481	263	13	484	263	17	.	*	..
7	417	253	33	420	255	13		*			*	..
8	363	246	31	366	247	15	.	*	..	..	*	.
9	314	237	.	317	239	.	..	*	..	..	*	..
10	271	229		273	231	.	.	*	..		*	..
11	232	222		236	225	..	.	*	..	237	227	.
12	198	217	..	202	217	..	..	*	..	202	219	.
13	168	211	..	171	213		.	*	..	173	217	..
14	143	206	..	145	207	.	.	*	..	147	213	.
15	120	200	..	122	202	.	.	*	..	125	208	..
16	101	199	..	103	199	.	..	*	.	105	203	..
17	84·4	200		85·9	197	.	90·9	200		88·1	201	..
18	70·8	201	.	72·0	197	.	76·3	197		73·9	196	..
19	59·7	202	.	60·4	199		63·9	193	..	61·9	197	..
20	50·2	204	.	50·9	203		53·1	195	.	51·7	197	..
21	42·3	208	..	..	..	.	44·7	199	.	43·3	200	..
22	35·9	211	..	..	.	.	37·6	201	.	36·4	203	..
23	30·5	213		..	.	..	31·7	203	..	30·7	206	..
24	25·8	213	.	..	.	..	26·7	205	..	26·0	209	..
25	21·9	215	..	.	.	..	22·5	207	.	22·0	212	..

* Breaks in the records.

The normal values of temperature and pressure in December and January in the free atmosphere over Agra, calculated from sounding-balloon ascents made at Agra a little before sunset to get rid of the effects of solar radiation, are given in *Table 5.*

TABLE 5.

Z = Height in geodynamic kilometers.
P = Pressure in millibars.
T = Temperature in absolute degrees.
N = Number of observations.

Z.	December.				January.			
	P.	N.	T.	N.	P.	N.	T.	N.
0·17	995·2	15	292	14	993·7	13	292	16
1	900·4	15	287	14	899·2	13	285	16
2	796·7	15	283	14	794·7	13	281	16
3	703·6	15	278	14	701·4	13	276	15
4	620·1	14	273	13	616·9	13	270	15
5	545 3	14	266	13	541·8	13	263	15
6	478·4	12	259	12	473·4	13	257	14
7	416·7	11	253	11	411·9	13	250	13
8	362·3	11	245	11	357·4	13	243	13
9	314·0	11	238	11	309 1	13	235	13
10	270·0	11	231	11	265·3	13	227	12
11	232·7	12	225	12	227·4	13	221	12
12	198·7	12	218	12	194·3	12	215	11
13	169 0	12	212	12	165·2	12	212	11
14	143·5	11	207	11	139·9	12	210	12
15	121·0	11	203	11	118·3	12	207	11
16	101·9	11	200	11	99·9	10	204	10
17	86·3	10	199	10	84·3	9	203	9
18	72·5	10	199	10	71·0	8	202	8
19	60·9	8	200	8	59·8	4	207	4
20	51·3	6	201	6	51·1	3	211	3
21	43·3	4	203	4	43·5	1	213	1
22	36·6	4	206	4	37·0	1	215	1
23	30·9	4	209	4	31·5	1	218	1
24	26·2	4	212	4	27·0	1	220	1
25	22·1	3	211	3	23·0	1	222	1

A comparison shows that on 22nd December between the levels of 15—19 gkms., on 23rd December between 18—25 gkms., and on 25th December between 18—25 gkms., temperatures are lower than the normal temperatures in December and January for the same levels. But for lower heights, from 2—10 gkms. on 22nd, from 2—6 gkms. on 23rd, and from 1—15 gkms. on 25th, temperatures are above the average values in December and January for the corresponding heights. These features are shown in *Fig 3.*

On 22nd December, between ground to 16 gkms. level, and on 25th December between ground to 20 gkm., pressure is higher than average values of pressure in December and January for the same levels. On 23rd December, between ground to 6 gkm. and between 17 to 25 gkms. pressure is above the normal values in December and January and in all probability this is also true for heights of 7—16 gkms.* for which data are lacking

It is noteworthy that these relations of temperature at different levels for the anticyclone under consideration are similar to those observed for anticyclones in Europe [6].

To account for moving anticyclones of mid-latitudes Exner has suggested that solid currents of air, extending from troposphere to stratosphere, move from tropical towards temperate regions. Douglas [7] has also emphasised the idea that the development of an anticyclone involves the transport of a ' high anticyclone ' consisting of tropical air over the subsiding polar air, and the more significant pressure changes are produced chiefly by large-scale horizontal movements of air-masses. The data given in *Table 4* lend support to the idea. The height and temperature of tropopause on these dates are as follows .—

19th December 1930	15 23 gkm.	199°·5 A.
22nd December 1930	16 20 gkm.	198°·6 A.
23rd December 1930	18·90 gkm.	193°·0 A.
25th December 1930	18 00 gkm.	196°·0 A.

On 23rd and 25th December, the levels of the tropopause are distinctly higher than the usual one for December and January, which is about 16 gkm. Compared to the temperature at different heights on 19th December 1930, the temperature on 22nd December 1930 has fallen from 17 gkm. upwards, and this decrease has become more marked on 23rd December from 18 gkm. upwards, but on 25th December the values of temperature for the same levels show a tendency to increase.

On 22nd, 23rd and 25th December, temperatures for the levels between 1·5—17 gkms., as far as available, are higher than those for the corresponding levels on 19th December.

The high levels of tropopause and the characteristic features of temperature and pressure in the upper air observed during the anticyclone can be accounted for by the supposition that the ring of cold air over the equator has broken through its boundary of warm air lying north and south of it. It has burst through the equatorial front, and moved towards North India, accompanied with a deep column of air practically extending throughout the whole of the troposphere. Probably this large scale advection of the tropical air had begun earlier than 22nd December, as the temperature at the heights of 15 and 16 gkm. on 19th December would seem to

* The normal values of pressure for 21—26 gkms. in January are unreliable. On 23rd December 1930, pressures at the heights of 24 and 25 gkms. are slightly below the average values in January for the same heights.

indicate. But in absence of meteorograph records on dates previous to 19th December 1930, one cannot speak with certainty on this point.

We now proceed to apply the theory of advection as outlined above.

As the soundings of 19—25 December refer to a sequence of phenomena of an anticyclone, all the meteorological elements are related to one another during the course of its development. There can be no objection, therefore, to calculate the values of π at different heights on 22nd, 23rd and 25th December with reference to 19th December. The alternative method of evaluating π on these dates with reference to the preceding date for which the sounding-balloon data are available has not been adopted here as there is a long region of break in the record of 23rd December. The second method would have enabled one to visualise directly the development from day to day, whereas the first gives the same picture indirectly. The values of π have been calculated from equation (1), and of δlp from (4). The progress of the anticyclone is shown in *Figs. 4, 5, 6,* values of π being shown in millibars against heights in geodynamic kilometers. In the π curve for 25—19 December values of π above 6 gkm. have been calculated from interpolated values of pressure and temperature for the levels 6—10 gkms., as there is a gap in that region in the record of 25th December. The values of π above 6 gkm. are therefore to be regarded as approximate only. But as these values bring out the general features quite well, these have been included in the graph.

To get rid of this uncertainty in the values of π on 25th December and to show the progressive changes on 22nd, 23rd and 25th December with respect to 19th December above 17 gkm. values of π are shown for these dates in *Fig. 7* *, taking $\pi=0$ for 17 gkm.

In the first π-*curve* for December 22—19, π decreases from ground to 1 gkm., showing that in this layer cold air has been brought in†. The cold dry air comes from North India as shown by the stream-lines of air in the chart giving winds at 1 km. level on 22nd December (see *infra*). Between 1 and 13 gkms., advection of warm air has taken place, and above that cold air. In the troposphere, a temperature-gradient exists from the equator to the poles, and *vice-versa* in the stratosphere. Thus a horizontal movement of a solid column of air, extending from stratosphere downwards, explains the cooling above and warming below the level of the tropopause approximately.

The second and third π curves for 22—19 December and 25—19 December show essentially similar features. But the region of sharp discontinuity at 1 gkm. in the first and second curve, marking the layer separating the warm air above from cold air below, has become smooth in the third curve. This may probably be due to the gradual mixing of warm air from above with the cold air below. Also

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*These values have been calculated after making a very slight modification in (1) resulting from the assumption that the adiabatic relation for a dry gas $p/T^{\frac{mCp}{R}} =$ constant holds good for the case, as the quantity of water vapour in the stratosphere is very small. Similarly δlp is obtained after a minor change in (4).

†For, if between the heights Z_1 and Z_2 ($Z_2 > Z_1$) π *diminishes* from $\delta\pi_1$, *to* $\delta\pi_2$, the mass $\delta\pi_1$ has poured in above Z_1, but only the mass $\delta\pi_2$ above Z_2. Therefore between Z_1 and Z_2, heavier, thus colder, air has been brought in. Similarly when $\delta\pi$ increases from Z_1, *to* Z_2, advection of warmer air takes place. The difference in values of $\delta\pi$ at Z_1 and Z_2, is equal to the difference in weight per unit cross-section of the new mass of air between Z_1 and Z_2 and the old air-mass occupying the same region.

on 25th December advection of less cold air is taking place above 15 gkm. as compared to that on 23rd December.

The second set of π curves, given in *Fig. 7*, clearly shows the transport of cold air above 17 kgm. on 22nd, 23rd and 25th December as compared to 19th December. Above the tropopause the development of the anticyclone was at its maximum on 23rd or 24th December, and it was on the wane by 25th December, as shown by the increase of temperature of air above 17 gkm.* on 25th December.

4. We shall now calculate the changes in temperature at different levels on 22nd, 23rd and 25th December with respect to 19th December. Equation (6) enables us to determine (i) the change in temperature due to the temperature of the air-mass, which displaces the original air, being different from the latter, (ii) the change in temperature due to adiabatic compression or rarefaction, and also (iii) the change in temperature due to vertical displacement of layers of air. If horizontal transport of air-mass from equatorial regions is chiefly responsible for the change of pressure, the change of temperature observed during the growth of an anticyclone will be caused by all the three factors. But according to the generally accepted idea†, the very slow sinking of the upper layers of atmosphere in such a system of circulation is accompanied by divergence in horizontal wind circulation in the lower layers of the atmosphere. When an anticyclone is unchanging and stationary, whatever subsidence and divergence are present are due to surface friction only, and hence their effect is quite small. According to Douglas[8], the rate of vertical descent in a developing anticyclone is of the order of 1 km. per day at 3 km level, and according to Shaw, the subsidence is 80 metres per day in a large high pressure area with small winds. Such a subsidence and divergence, however small the effects may be, will be accompanied by a change in cross-section of the sinking air mass. Equation (6) however does not take into account change in temperature due to this cause Margules[9] has derived a formula by which the variation in temperature due to variation in cross-section of an air mass can be calculated but unfortunately it cannot be applied to this case, as the change in cross-section cannot be experimentally determined. Nevertheless the variation of temperature at different levels as calculated from (6) on 22nd, 23rd and 25th December with respect to 19th December agree closely with the observed changes, considering the degree of accuracy of the data of temperature and pressure obtained by sounding balloon meteorographs and also the fact that effect of humidity has been left out of account. The results are shown in *Tables* 6, 7 and 8. It is noticed that the calculated and observed change in temperature on ground and at 1 gkm. approximately, do not show any agreement, as is to be expected, for the theory does not allow for the effects of radiation and turbulence which are predominant in that region. Also on 22nd December the variation in temperature at 14, 15 and 16 gkm. due to the incoming air-mass is found to

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***Two causes may be responsible for the increase of temperature on 25th December above the tropopause. Firstly, the temperature of the cold air-mass brought in before that date may gradually increase, as compared to that on 23rd December by adiabatic compression due to the increase of pressure above due to the cold air-mass. Secondly, the cold air transported in the beginning of the process, will gradually acquire the temperature characteristic of the latitude, if air from the equatorial regions ceased to pour in Both the causes may be operating simultaneously**

†It may be of interest to describe here the picture of an upper anticyclone as sketched by Rossby. The injection of a cold air-mass in the upper atmosphere at a height *h* is accompanied by compression of the lower layers (it can be shown mathematically that higher the level of advection the greater is the compression of the lower layers of atmosphere). The compression of the lower layers causes the atmosphere above *h* to sink bodily thus creating a deficiency of pressure above This very weak depression does not allow the air column to sink fast, the slow sinking or subsidence of cold air being accompanied by a slow outflow below the cold air column, while the depression above is being slowly filled up by drawing air from all sides.

TABLE 6.

Change in temperature on 22nd December 1930 with respect to 19th December 1930 calculated according to different terms of equation (6).

Height (gkm).	First Term °C.	Second Term °C	Third Term °C	$\delta_t T$ Comp. °C	$\delta_t T$ Obs. °C.
0·17	—4·8	—0·1	0·0	—4·9	0·0
1	0·0	—0·2	0·0	—0·2	—1·0
2	5·1	—0·6	0·0	4·5	3·0
3	4·2	0·1	0·0	4·3	6·5
4	3·7	0·3	0·0	4·0	4·5
5	3·3	0·4	0·0	3·7	4·5
6	2·2	0·6	0·0	2·8	3·5
7	2·4	0·8	—0·1	3·1	1·5
8	2·3	1·0	—0·2	3·1	1·5
9	2·0	1·2	—0·3	2·9	1·5
10	0·7	1·4	—0·5	1·6	2·5
11	0·2	1·6	—0·5	1·3	2·5
12	0·0	1·9	—0·6	1·3	0·5
13	0·0	2·1	—0·5	1·6	2·5
14	—0·8	2·5	—0·6	1·1	1·0
15	—1·2	2·7	—0·8	0·7	2·0
16	—1·7	3·1	—0·1	1·3	0·5
17	—4·5	3·4	0·4	—0·7	—3·0
18	—8·5	3·6	0·3	—4·6	—4·5
19 ..	—10·7	3·8	0·4	—6·5	—3·5
20 . .	—9·7	4·3	0·5	—4·9	—1·0

TABLE 7.

Change in temperature on 23rd December 1930 with respect to 19th December 1930 calculated according to different terms of equation (6).

Height (gkm).	First Term °C	Second Term °C	Third Term °C	$\delta_t T$ Comp °C	$\delta_t T$ Obs °C.
0·17 ..	—1·0	0·0	0·0	—1·0	—1·5
1	0·0	0·0	0·0	0·0	—0·5
2	4·0	0·1	0·0	4·5	5·0
3 ..	6·6	0·3	0·0	6·9	6·2
4	6·2	0·6	0·0	6·8	7·5
5	3·6	0·9	—0·1	4·4	4·5
6	2·2	1·1	—0·1	3·2	2·5

TABLE 8.

Change in temperature on 25th December 1930 with respect to 19th December 1930 calculated according to different terms of equation (6).

Height (gkm)	First Term °C.	Second Term °C.	Third Term °C.	$\delta' T$ Comp °C.	$\delta' T$ Obs. °C
0·17	—1 8	0·9	0·0	—0·9	—4·5
1	—0 7	0·0	0·0	—0·7	1·0
2	3 4	0·0	0·0	3·4	5·5
3	5·8	0·3	0·0	5·3	6·0
4	2 7	0 5	0·0	3·2	4·0
5	2 0	0 6	—0·1	2·5	3·0

be negative whereas a rise of temperature has been registered by the meteorograph. The reason is quite apparent ; for the rise in temperature due to adiabatic compression exceeds the fall in temperature caused by the transport of cold air. From 17 gkm. a net decrease in temperature is noticeable as the fall in temperature due to advection exceeds the rise caused by adiabatic compression.*

5. We now turn our attention to the stream-lines of *upper air*, as revealed by pilot balloon ascents and directions of movement of clouds between 7 and 11 hours I. S. T. The scale of velocities of upper winds is given in *Fig.* 8. The stream-lines at different heights above mean sea level for which sufficient data are available† have been drawn, and motion of cirrus clouds is shown in the charts for the 9 km. level. As the run of isobars is not known, the separation of lines of flow is to be regarded as only approximate An anticyclone, bringing in cold northwesterly wind, characteristic of the winter season in Upper India, had existed from ground to 1 km. level with centre over different parts of North-West India, Baluchistan and Sind for about three weeks before 19th December 1930. At 1 km. level, the centre of the system was also occasionally found over Central India, Central Province, North Deccan, Gujarat and the neighbourhood of the Arabian Sea At 4—6 km. levels, an anticyclone generally occupied the region over India and the neighbouring seas between Lat. 20°N. and 12° N., where normally a ridge of high pressure[10] exists in Dec.- Jan at these levels. Due to it, air was brought in over these latitudes from WNW, W or WSW and occasionally from SW direction also, At 2—3 km. levels, anticyclones existed with cores coinciding either with those at 4 km. or at 1 km. but these cores were also found over regions intermediate between those over which the centres at 1 km. or 4 km. existed ‡

The winds at 4 and 6 km. levels, for which sufficient data are available, were brought in from W and WNW directions on 19th December by the anticyclonic circulation at these heights. On 20th § December the wind due to this high

*The difference between observed and calculated values of temperature at 19 and 20 gkm is rather high, and this may probably be due to errors in observation

†The maps for 3 and 5 km levels have been omitted, being considered unnecessary as the data for 2 and 4 km are sufficient to bring out the main features

‡In this brief description, it is not possible to describe in detail the position of the centres of the anticyclonic system at different levels, but this summary will be found sufficient for following the subsequent progress of the anticyclone under consideration

§On 20th December the winds at Bangalore (Lat. 12° 58′ N. Long 77° 36′ E.) between 19 to 22 kms were from S and SE directions, but not exceeding 15 miles per hour

On 21st December the winds at Sambalpur (Lat. 21° 28′ N. Long. 84° 01′ E.) between 17 to 8 km. were from SW direction with velocity 65 miles per hour.

was also from westerly and northwesterly directions at 4 km. but at 6 km. the circulation brought in winds from south-west. The cirrus-movement over *Lower India* was also from *south-west and south.*

From the charts it is seen that the high, which was over Hyderabad and Kathiawar on 20th December 1930 at 4 km. and 6 km., has moved over central parts of India at these levels on 21st December 1930. It also probably exists at 7 and 8 kms. over these regions.

The same features of south-westerly winds are marked in the morning charts of 21st December for 6 km. and cirrus-level Also at 4 km. on 21st December the winds over central parts of India are flowing from southwesterly direction. On the morning of 22nd December the anticyclone with its southwesterly winds over central parts of India has moved at 4 and 6 km. levels into more northerly regions as compared to that on 20th and 21st December. But winds at heights of 1 and 2 km. due to the anticyclone at these levels are still pouring in from North-West India, and this feature is also noticed in the charts for 19—21 December.

On 23rd December the progress in the northerly movement of the anticyclone at 4 and 6 km. bringing in south-westerly air from the Arabian Sea can be seen. The cirrus-movement shows that a southwesterly current has penetrated North-West India, and the sounding balloon record on the evening of 22nd December gives a definite evidence to the transport of tropical air over Upper India. The centre of the anticyclone at the level of 2 km. bringing in north-westerly air on 22nd December has merged into a high pressure region on 23rd December over central parts of the country circulating the air in a closed oval over the land, but at 1 km. the features noticed on the previous dates remain unaltered.

On 24th December the winds at 6 2 kms. are now seen to come from a south-easterly direction from the Bay of Bengal under the influence of the anticyclone, which also exists at the cirrus-level, as shown by the movement of cirrus-clouds from a south-westerly direction.

The centre of the system at 6 km. on 24th December is over Lower Bengal and the head of the Bay of Bengal. At 4 kms. it lies over Bihar, Orissa, Chota Nagpur and the adjoining portions of the Bay of Bengal, while at 2 km. a high pressure area exists over Rajputana and the adjoining parts of India and another over the head of the Bay of Bengal.

On 24th the anticyclone bringing in north-westerly winds at 1 km. still persists, but on 25th December a closed high pressure area over Rajputana and Central India appears.* At 2 km. on 25th December the two regions of high pressure mentioned in the preceding paragraph have joined to form a ridge of high pressure over the central parts of the country and upper regions of the Bay, otherwise the general features from 4 to 6 km. level and at cirrus-level are the same † on 25th December.

It may be mentioned here that on the surface chart of 25th December (not shown) a high pressure area with light winds existed over North-West India, Central India and United Provinces.

The gradual withdrawal of the anticyclone from Upper India is noticeable on the charts of 26th December.

---

*Attention may be drawn to the π curve for 25th—19th December in which the sharp discontinuity at 1 gkm level noticed in the curves of 22—19 and 23—19 December has been smoothed out due to this reason

†A slight increase in relative humidity on the ground is noticed on 23rd December. This is due to the fall in temperature on the ground and not to any change, caused by advection, in the properties of the existing mass of air.

In comparison to that on 19th December humidity on 22nd and 23rd December generally decreased at all levels above 1 gkm. for which data are available. This is to be expected from the rise in temperature above 1 gkm. under the influence of the anticyclone. Compared to that on 22nd December, humidity is higher on 23rd December† from 1 to 3 gkm., above which it is either practically equal to or just greater than that on 22nd December, though the temperatures on 23rd December are either higher than or equal to those for the same levels on 22nd December. This increase of humidity on the evening of 23rd December is due to moist air from the Bay of Bengal brought over Upper India under the influence of the anticyclone. The subsequent increase in relative humidity on the evening of 25th December at the level of 1 gkm. and above is due either to a further increase of moisture or to the decrease in temperature. The observed increase in relative humidity will be accounted for by the simultaneous effect of both the causes.

It is seen from the above that an upper anticyclone was brought into existence by the advection of tropical air into northerly latitudes at high levels above the tropopause, and the anticyclone thus formed then extended into lower levels. The lower anticyclone existing from ground to 4—6 kms. on 19th December and previous dates, which brought in north-westerly air over Northern India was gradually absorbed by or merged into the upper system. Both existed thereafter as an anticyclone continuously from 1 km. up to the tropopause and probably above it also But with the data available at present it has not been possible to find out the cause of this large-scale transport of tropical air, also it is not possible to say whether the interaction, if any, between the upper air at high levels and the anticyclone at lower levels was responsible to any degree for this movement.

The writers wish to record their best thanks to Mr G. Chatterjee, Meteorologist-in-charge, Agra, for placing the sounding balloon data at their disposal and to Mr. D. M. Patel, Assistant Meteorologist, for very kindly calculating some of the π curves for the senior author.

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1 Chatterjee and Sur The Thermal Structure of the Free Atmosphere over Agra. Gerlands Beitrage Zur Geophysik, Volume 25, 1930, page 276, Fig 7

Briefly speaking the characteristics of these types of tropopause are as follows —

A Abrupt change in lapse rate from a positive to a negative value at the tropopause

B. At the tropopause, a marked change in lapse rate, first from a comparatively large positive value to a small positive or zero value, and finally to a negative value

C Gradual change in lapse rate from a positive to a negative value, the tropopause being fixed at the point where the lapse rate is 2°A per kilometre or less, it being not exceeded in higher levels

2 Gold Geophysical Memoirs, London No. 5, 1913, pages 110—111.

3 Chatterjee and Sur, Loc. cit page 227, Fig 7.

4 Exner, Uber den Einfluss von Luftdruckveranderungen auf die Vertikale Temperaturverteilung, Koppen Heft der Annalen der Hydrographie, Berlin, 1926.

Also, Haurwitz, Einfluss von Massenanderungen in grossen Hohen auf die Vertikale Temperaturverteilung, Met Zeits, July 1927, pages 253—260

5 Rossby, Studies in the dynamics of the stratosphere, Beit Zur. Phys. der Freien Atmosphare, Band 14 1928, pages 240—265

6. W H. Dines, Cyclones and anticyclones, Journal of the Scottish Meteorological Society, Third Series, Volume 16, 1914, pages 304—312.

7. Douglas On some aspects of surfaces of discontinuity, Quar. Jour. Roy. Met. Soc., Volume 55, 1929, page 133.

8. Douglas, loc., cit., p. 134.

9. Margules, Met. Zeit., Bd. 23, 1906, p. 241.

10. Banerji and Ramanathan, Upper Air Circulation over India and its neighbourhood up to the cirrus level during winter, India Met. Dep. Scientific Notes, Vol. III, No. 21, 1930.

†Vide *footnote on preceding page.*

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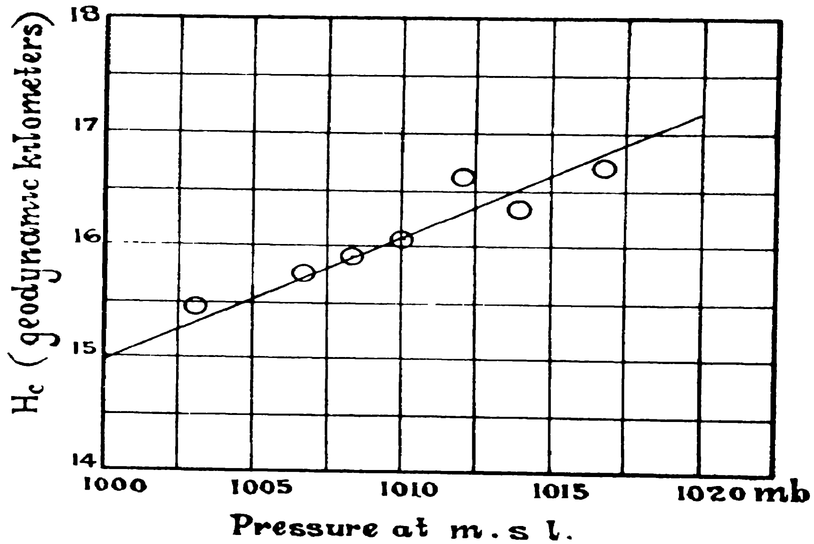
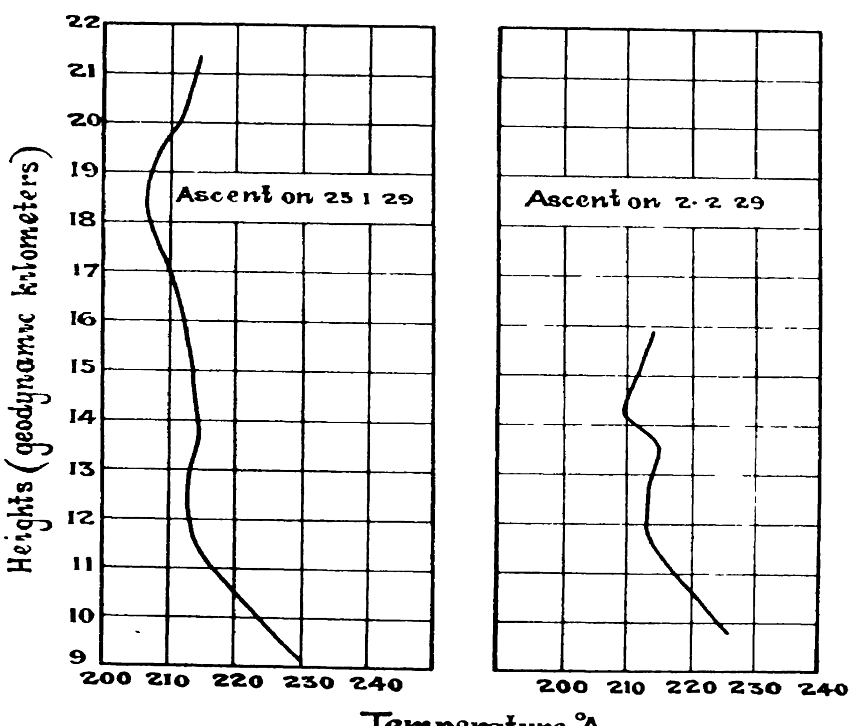


Dec-Mar.

Fig 1



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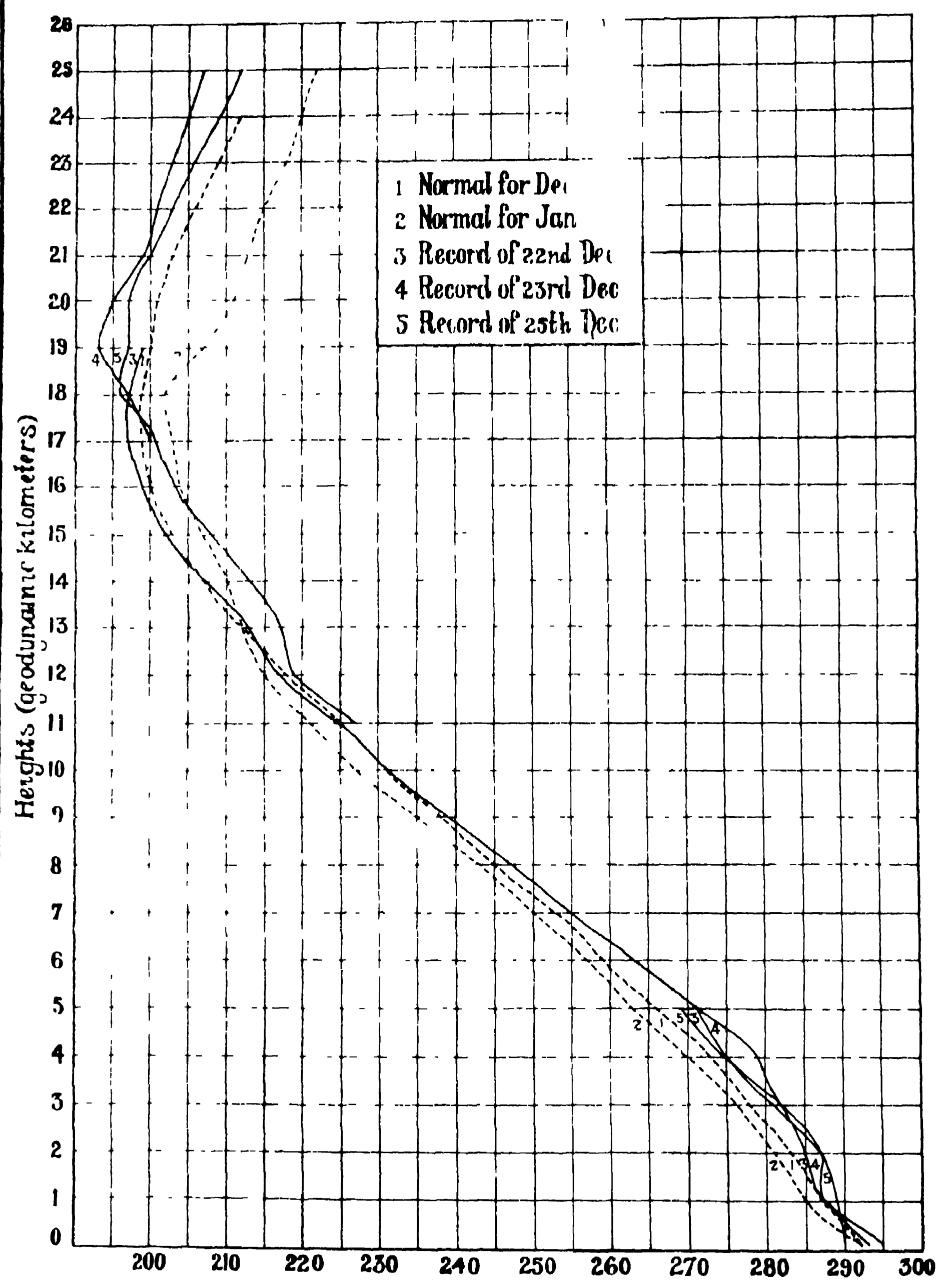
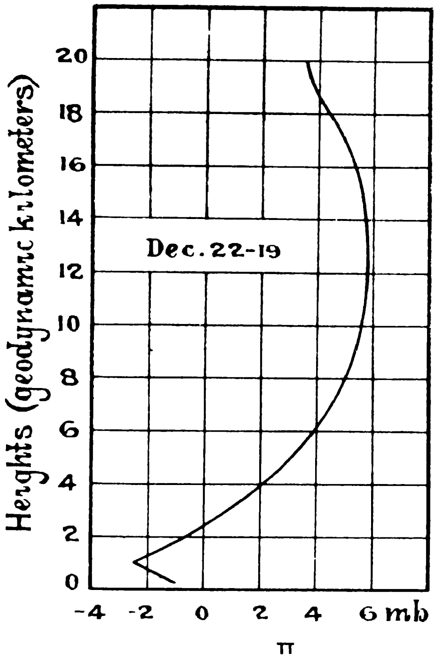


Fig 3

G P Z O POONA 1932



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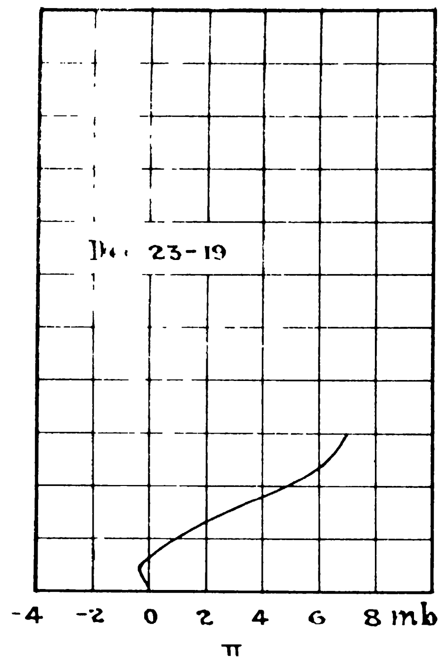

Fig. 5

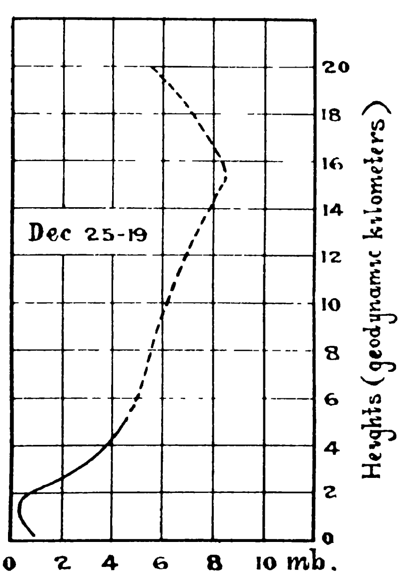

Fig. 6

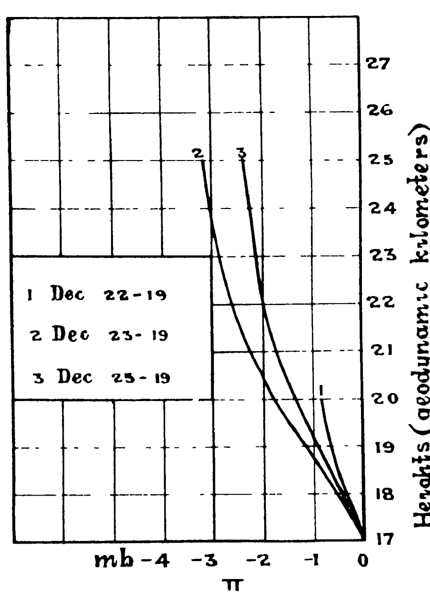

Fig. 7

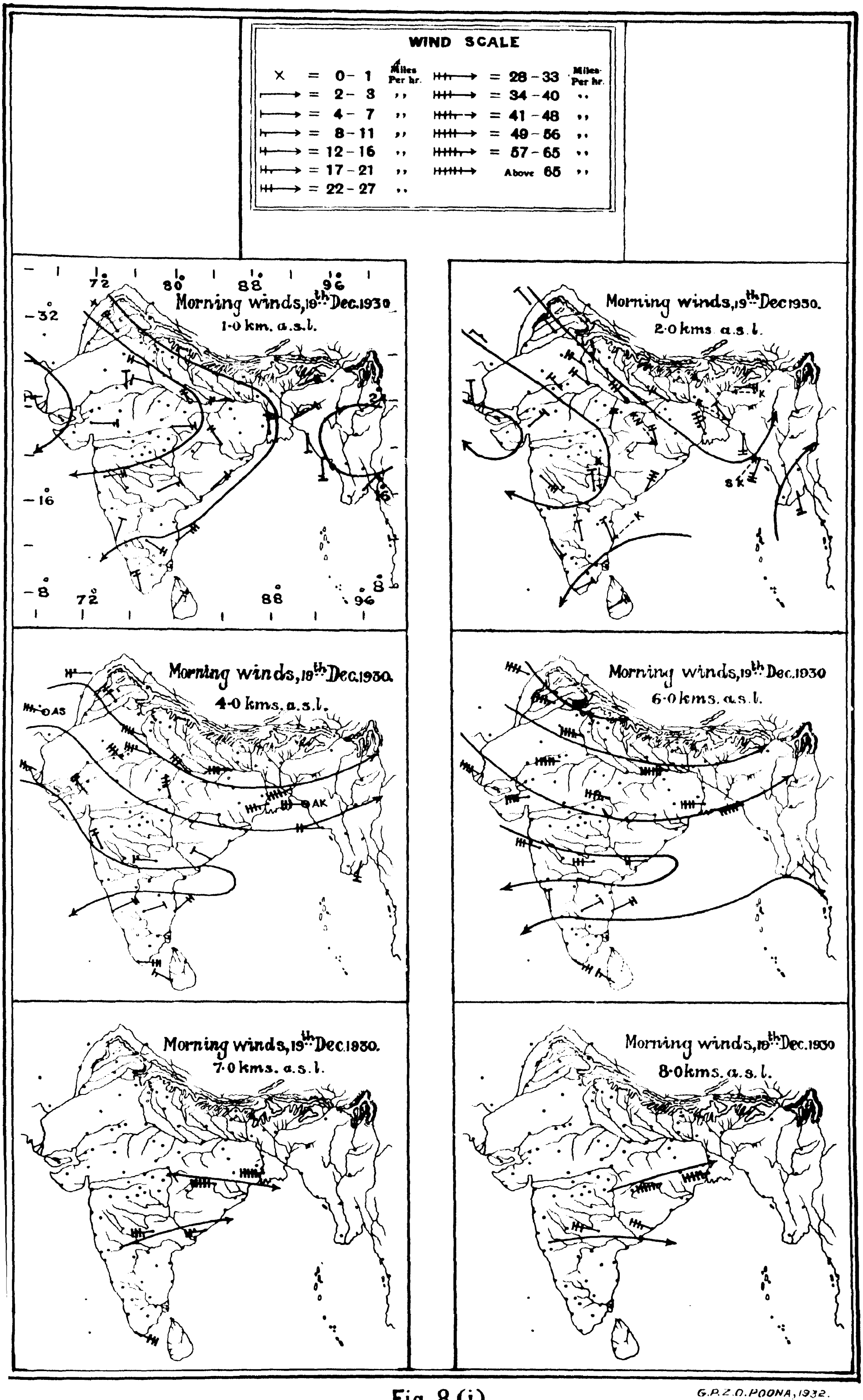

Fig. 8 (i)

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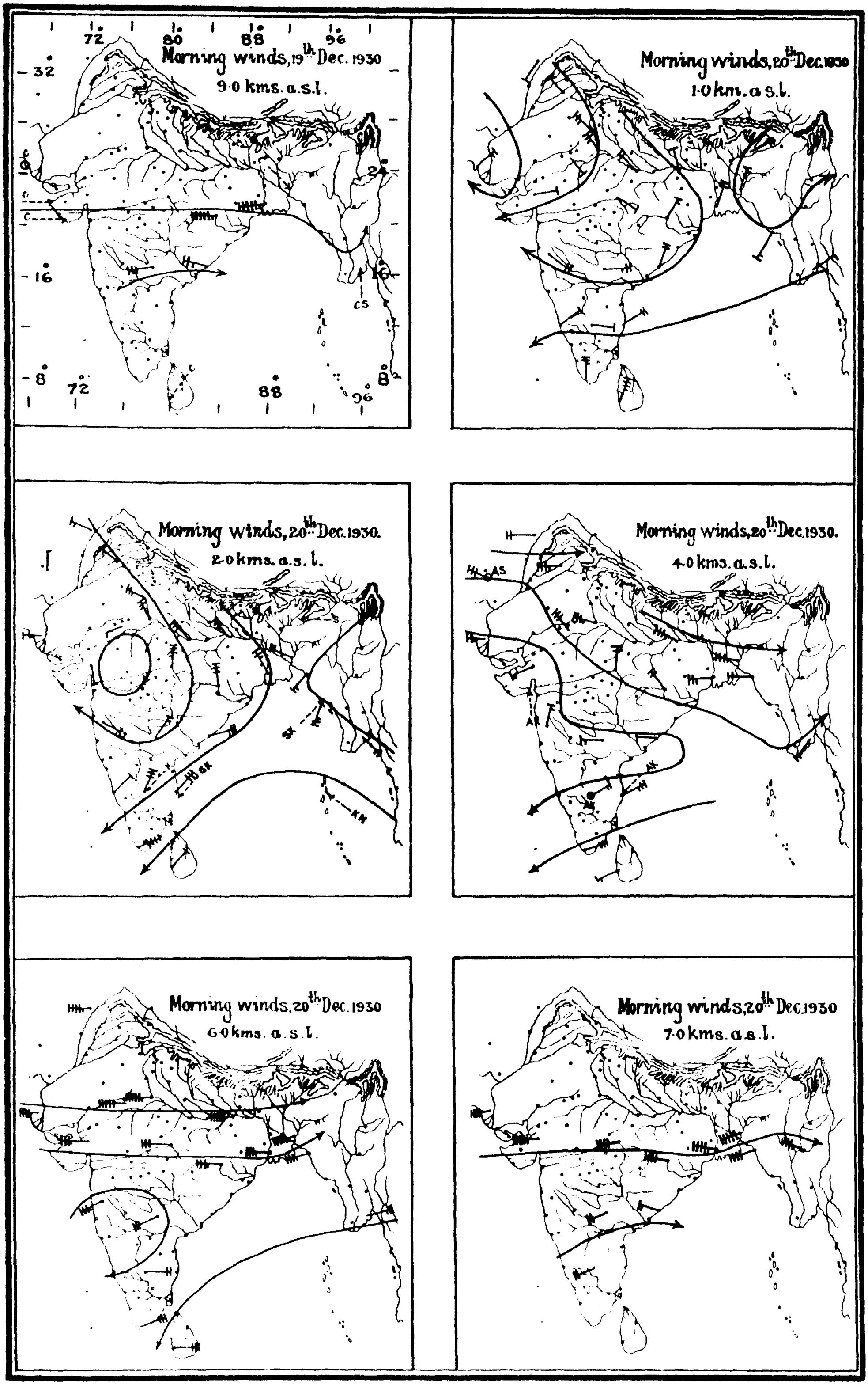

Fig. 8 (ii)

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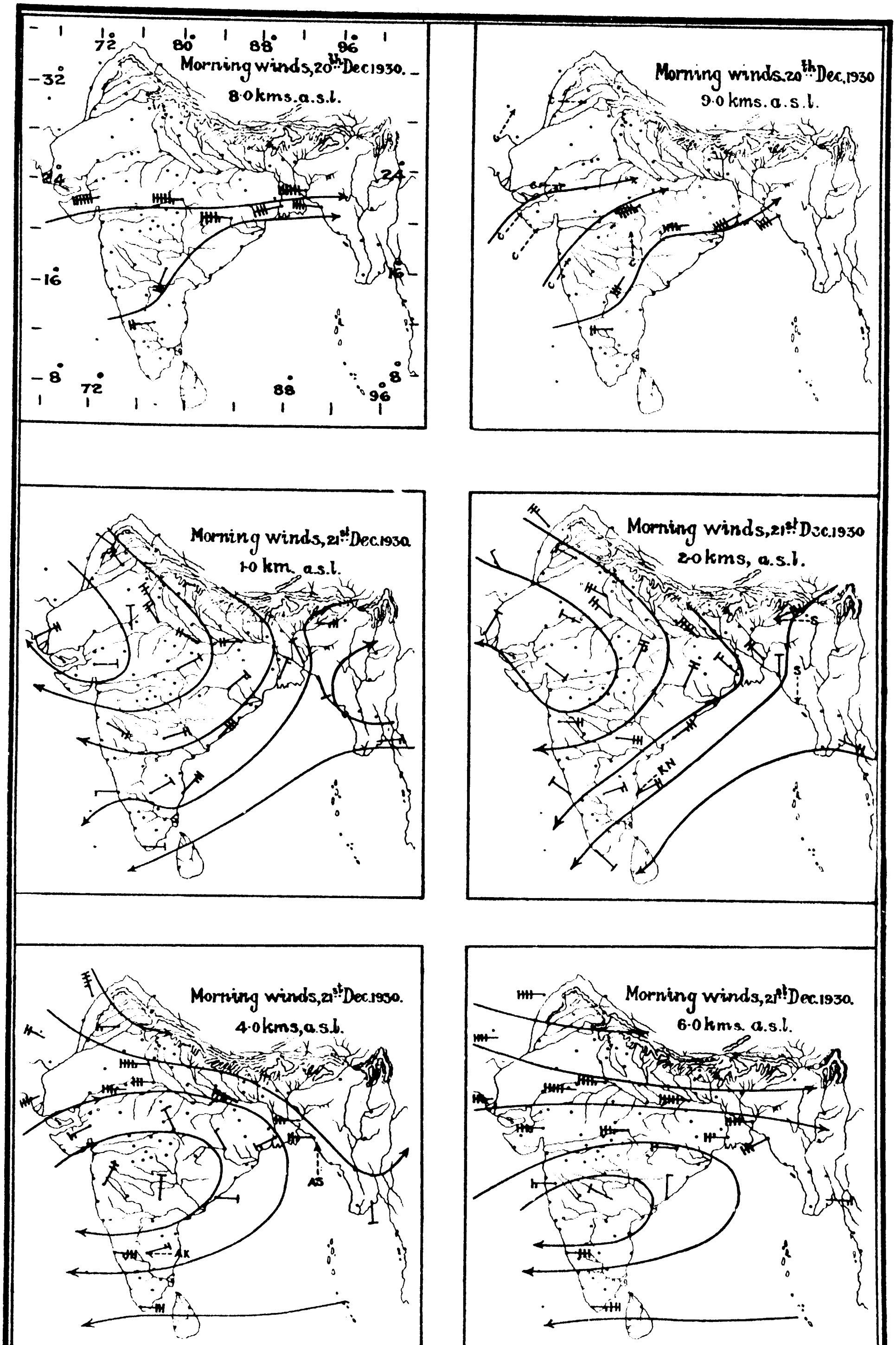
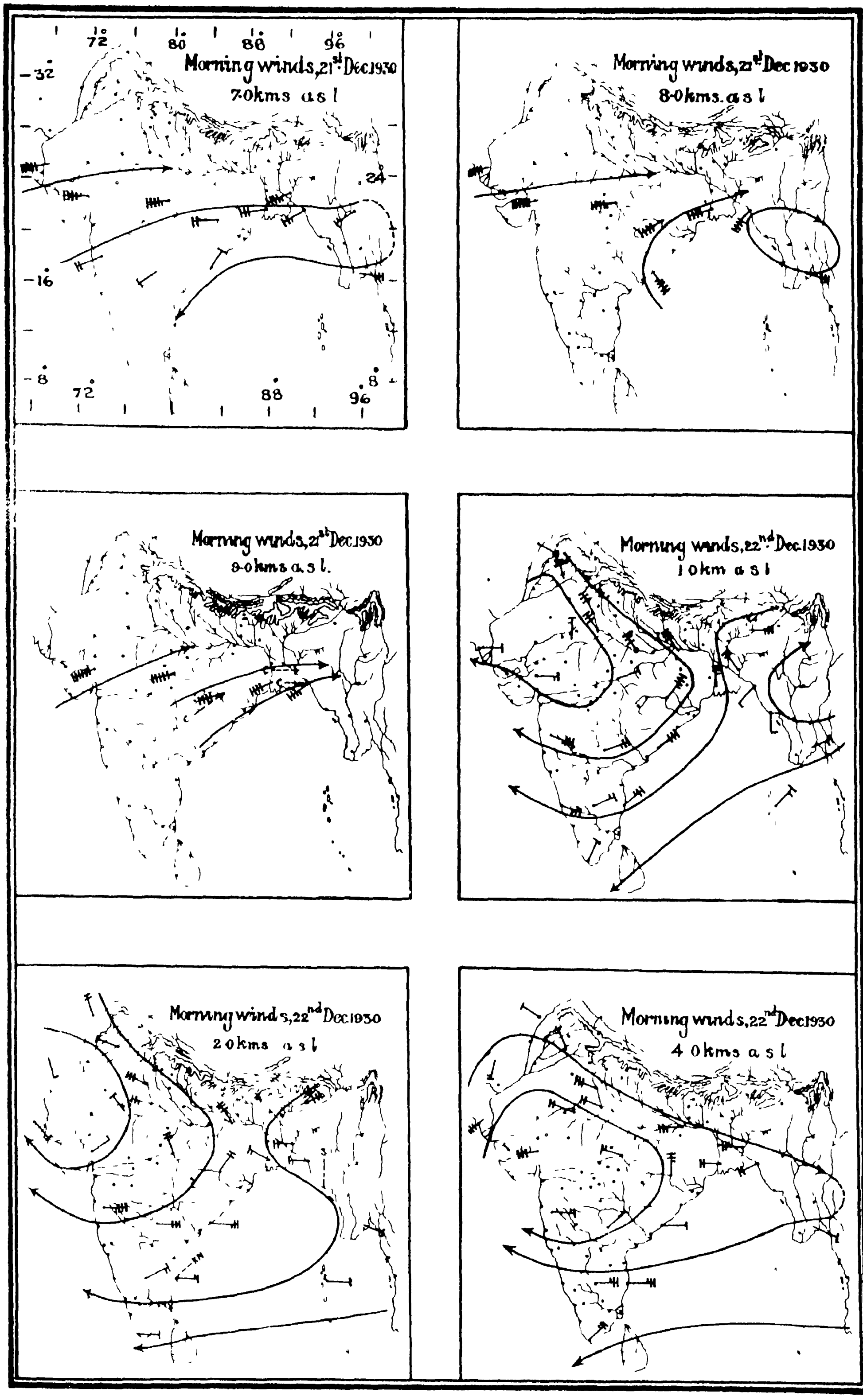


Fig. 8 (iii)

G.P.Z.O POONA, 1932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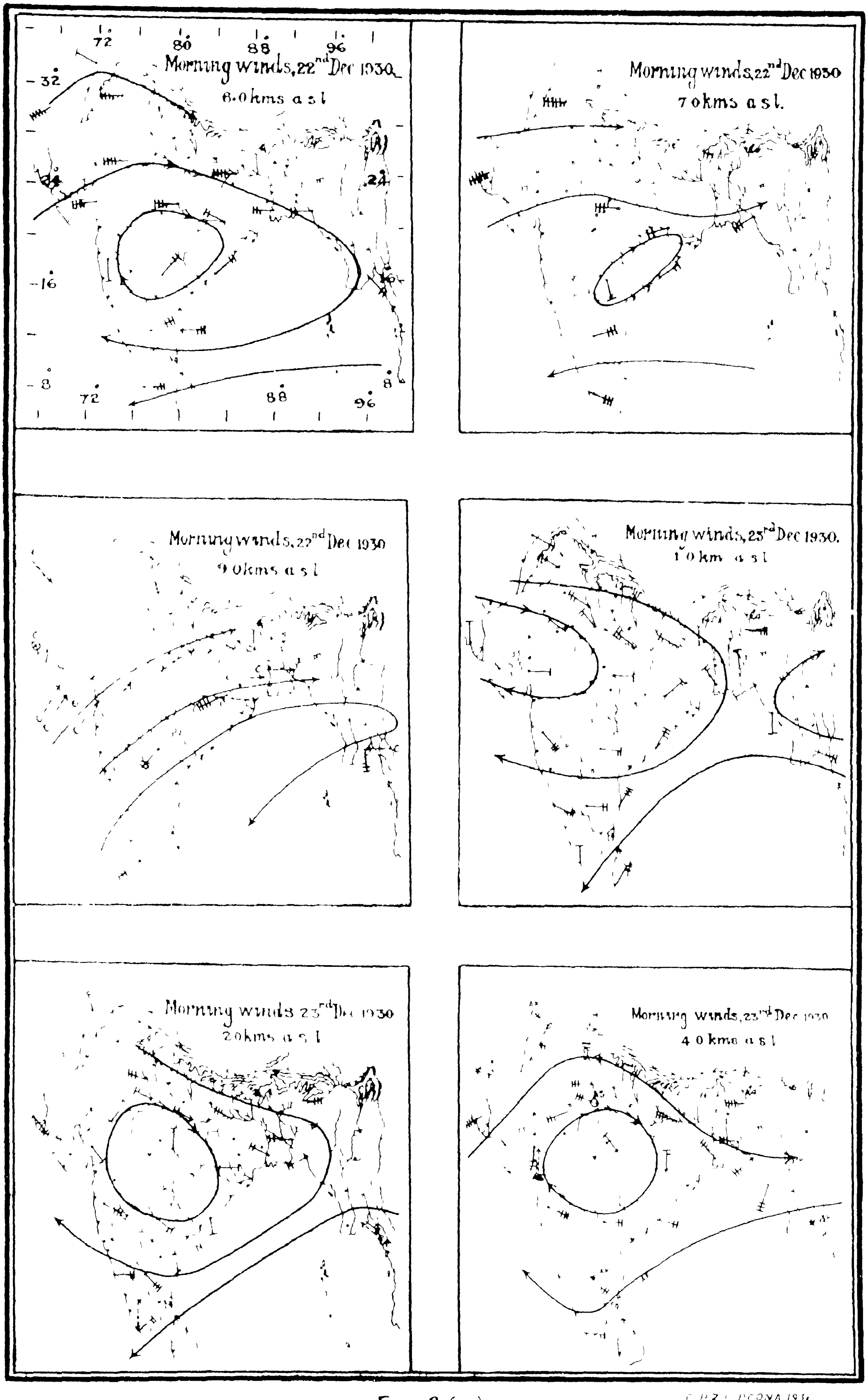
Morning winds, 21st Dec 1930
8.0 kms. a s l
Morning winds, 21st Dec 1930
9.0 kms a s l.
Morning winds, 22nd Dec 1930
1.0 km a s l
Morning winds, 22nd Dec 1930
2.0 kms a s l
Morning winds, 22nd Dec 1930
4.0 kms a s l

Fig 8 (iv)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6.0 kms a s l
72
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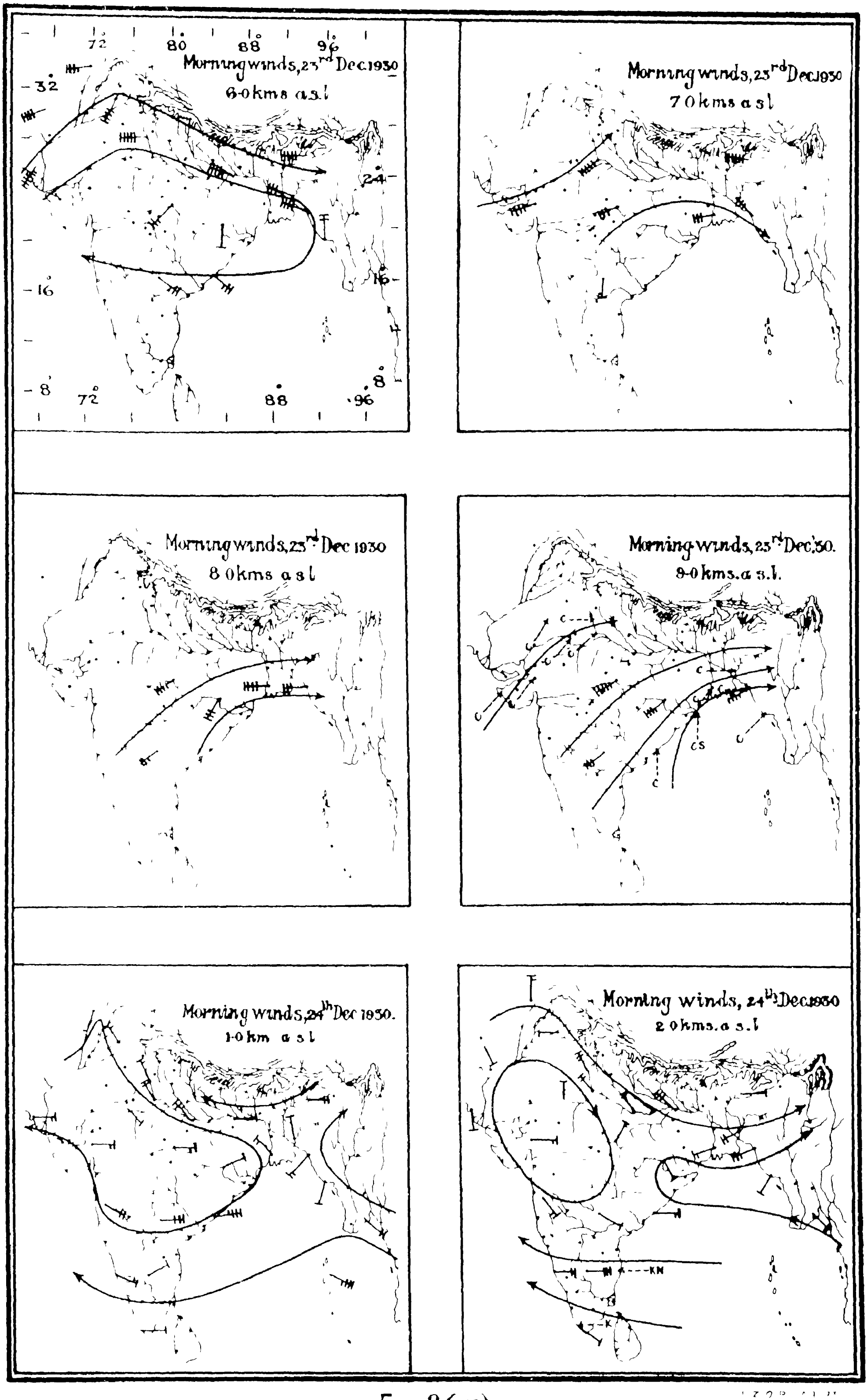
Morning winds, 22nd Dec 1930
7.0 kms a s l.
Morning winds, 22nd Dec 1930
9.0 kms a s l
Morning winds, 23rd Dec 1930.
1.0 km a s l
Morning winds 23rd Dec 1930
2.0 kms a s l
Morning winds, 23rd Dec 1930
4.0 kms a s l

Fig 8 (v)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Morning winds, 23rd Dec 1930
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Morning winds, 23rd Dec 1930
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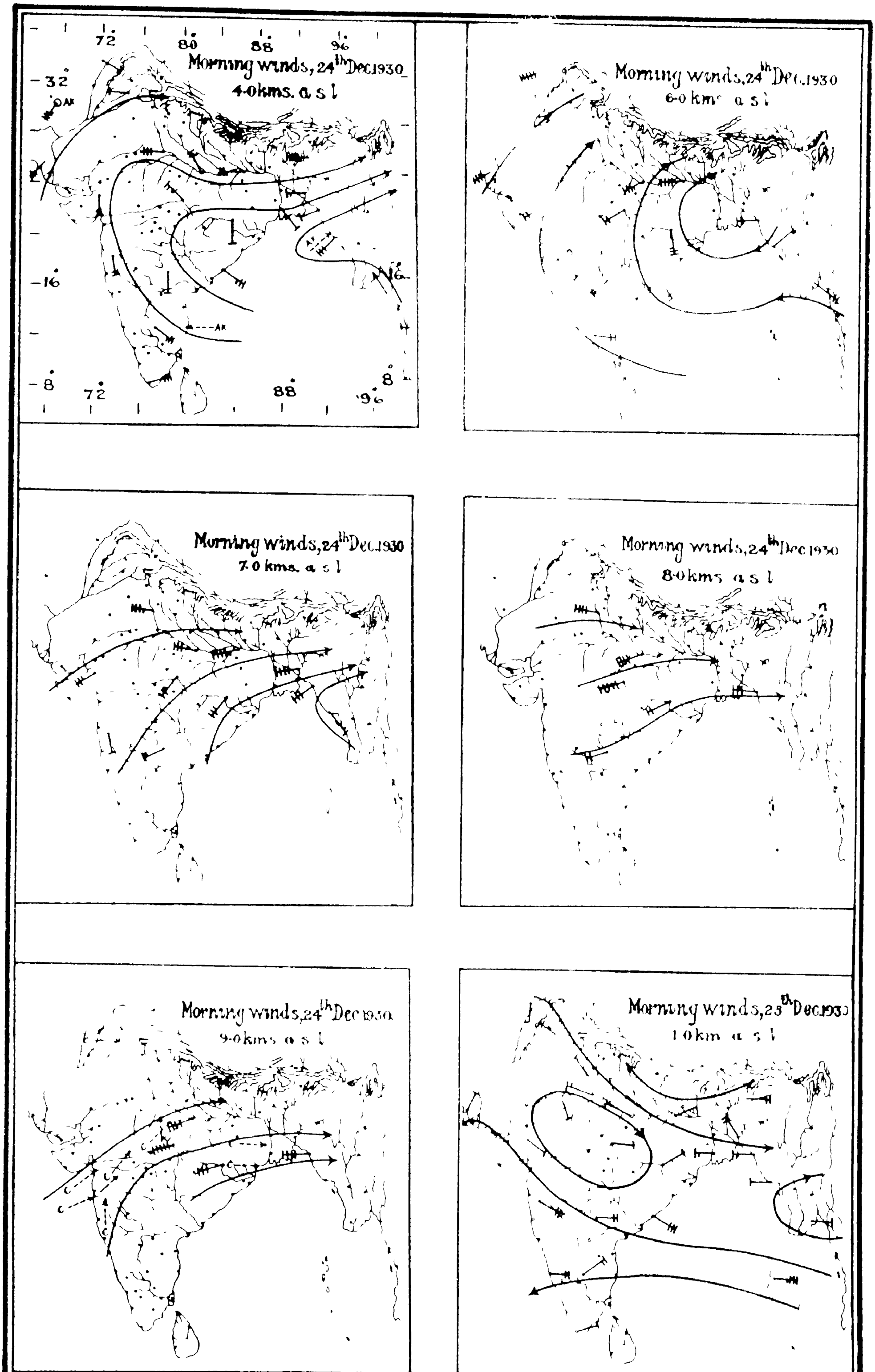
Morning winds, 23rd Dec '30.
9·0 kms. a.s.l.
Morning winds, 24th Dec 1930.
1·0 km a.s.l.
Morning winds, 24th Dec 1930
2·0 kms. a.s.l.

Fig 8(vi)



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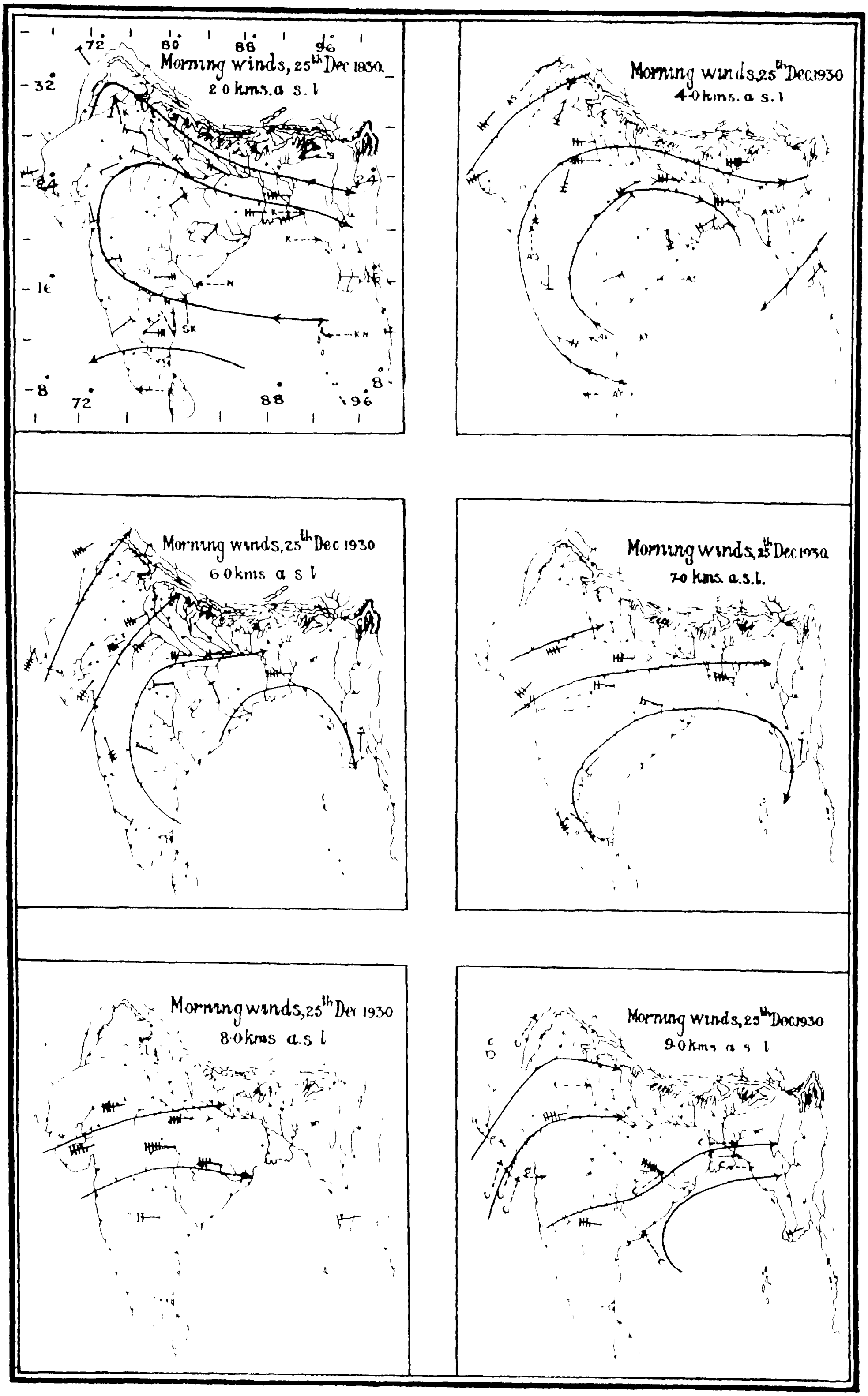
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Morning winds, 25th Dec 1930
4.0 kms. a s. l
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6.0 kms a s l
Morning winds, 25th Dec 1930
7.0 kms. a. s. l.
Morning winds, 25th Dec 1930
8.0 kms a. s. l
Morning winds, 25th Dec 1930
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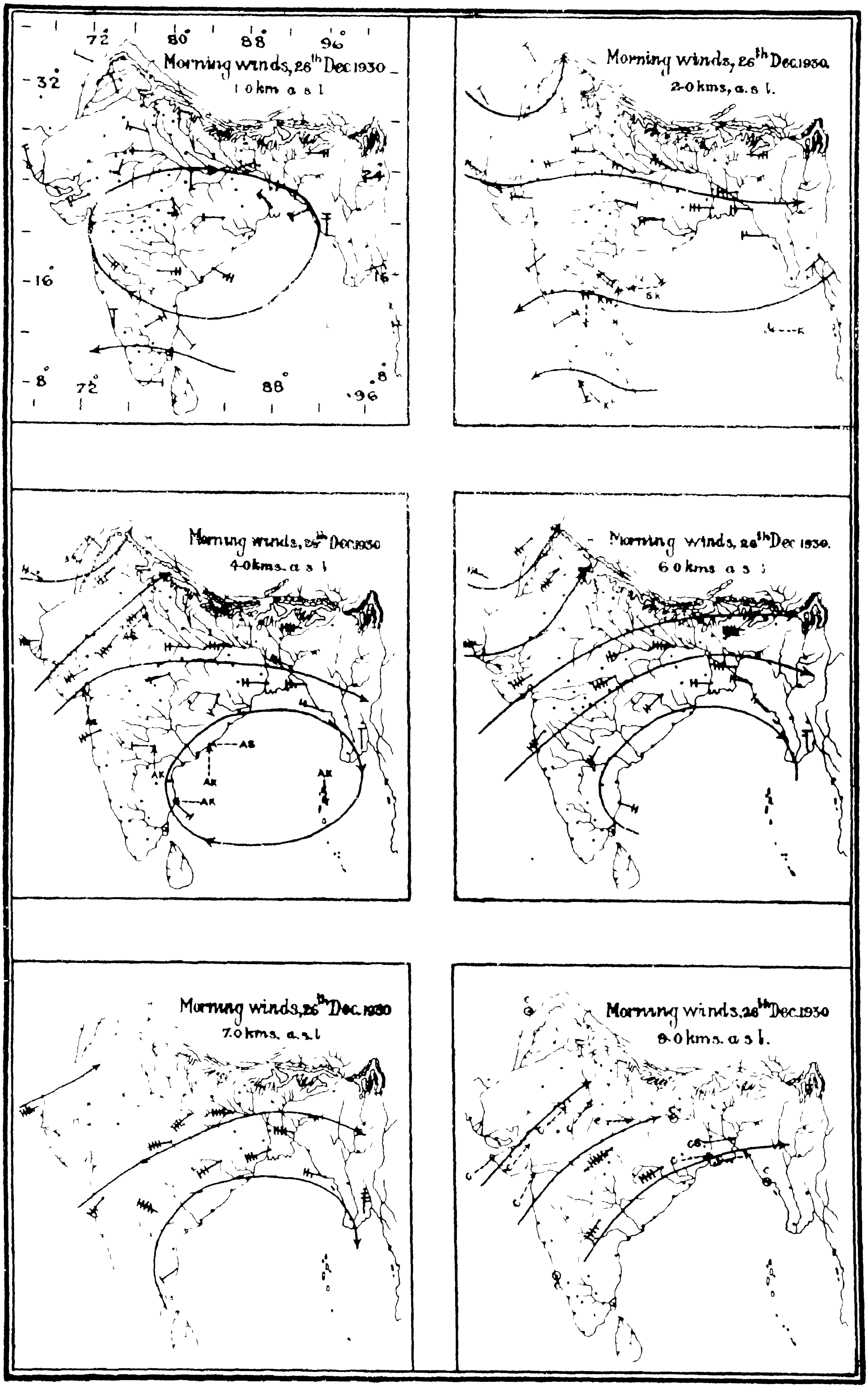
Fig. 8 (viii)



72
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96
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Morning winds, 26th Dec 1930
1.0 km a.s.l.
Morning winds, 26th Dec 1930
2.0 kms, a.s.l.
Morning winds, 26th Dec 1930
4.0 kms. a.s.l.
Morning winds, 26th Dec 1930.
6.0 kms a.s.l.
Morning winds, 26th Dec 1930
7.0 kms. a.s.l.
Morning winds, 26th Dec 1930
8.0 kms. a.s.l.

Fig. 8 (ix)

INDIA

METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. V, No. 46.

On Solitary Gusts associated with Reversals of Pressure Gradients

BY

S. ATMANATHAN, M.A.

(Received on 13th October 1931.)

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(VOLUME V)

Number 46.

ON SOLITARY GUSTS ASSOCIATED WITH REVERSALS OF PRESSURE GRADIENTS

BY

S. ATMANATHAN, M.A.

(*Received on 13th October 1931.*)

Summary.—Solitary gusts or squalls of short duration sometimes occur during periods of calm intervening successive pulses of katabatic air movements at Poona. Each of these gusts consists of a steady rise of wind force from calm to its maximum value, followed by a steady fall to calm again, with a duration of from 3 to 15 minutes, and the onset of the gust is accompanied by a sudden change of direction to that of the gradient wind. Changes of pressure and temperature associated with the gusts are examined, and the latter are shown to be due to the passage of fronts of pressure discontinuity following the reversal of the forced gradients established by the katabatic movements, when these terminate.

1. Introduction.—The Meteorological Office at Poona being situated near the confluence of two river-valleys, the winds recorded by the anemographs possess several interesting features depending on local orography. Some of these have already been discussed by the author in an earlier number of this publication[1]; another is the occurrence of solitary gusts of wind during the night rising steadily from calm to anything from 4 to 20 miles per hour, and then subsiding to a calm again, the complete process occupying an interval of from 3 to 15 minutes. The anemographic record of this phenomenon may be likened to a tall isosceles triangle standing on a very short base. It is found that the gusts are almost always associated with katabatic movements, although there are occasions when they occur at the conclusion of the sea-breeze, which in the earlier months of the year penetrates from the Arabian Sea as far inland as Poona[2]. Sufficient attention does not appear to have been paid to this phenomenon hitherto, although the subject possesses considerable theoretical interest.

The chief features of the topography and climatology of the district round Poona have been described by the author in the paper[1] referred to above. The Meteorological Office and Observatory are situated about a mile to the west-southwest of the confluence of the two streams, the Mutha and the Mulla. The valley of the former lies directly to the southwest and that of the latter to the north-northwest across a saddle in the line of hills to the west. The Mutha valley is the narrower, steeper and the straighter of the two. The combined stream meanders along a wide gently sloping basin to the east.

Winds of katabatic origin occur at Poona on almost all clear and calm nights, which are many in the months October to April. These movements are pulsatory

in character, consisting of alternate periods of light winds and calm the winds being mostly from the SW but sometimes from the NNW. These months are also characterised by feeble gradient winds with prominent easterly components, but the gradients are so small that the surface winds never attain appreciable velocities, especially during the nights. This is also the season in which nocturnal inversions near the ground are common.

2. **Velocity, Duration and Time of occurrence of the Gusts.**—Dines' P. T. anemograms at the Meteorological Office at Poona for the two years May 1929 to April 1931 were examined and the occasions on which solitary gusts occurred have been tabulated in the Appendix, where information is also furnished as to the maximum velocity attained, the duration and the change of wind direction at the passage of each gust. It will be found that the maximum velocity of the gust varies from 3 m. p. h. to 24 m. p. h. These however are the values actually recorded on the anemogram, and a correction (of the order of 5%), required to be added on account of the lower value of the density of air, has been neglected owing to the smallness of the magnitudes involved The duration also is largely variable, although one of 3 to 8 minutes appears to be the most frequent In most of the cases, the gust occurs when the wind direction changes from the southwesterly of the katabatic movement to the east or northeast of the prevailing seasonal gradient wind , a few occur with a change from the north-northwesterly direction of the katabatic wind or the sea-breeze, while gusts accompanying the opposite changes are comparatively rare. In a majority of cases, the change of direction amounts almost exactly to two right angles.

In the following table are set out data of frequencies of occurrence of the phenomenon at the different hours of the night for different ranges of the maximum velocity of the gust :—

Hrs. (I. S. T.) / Velocity of gust. (m. p. h.)	Before 20	20—21	21—22	22—23	23—24	00—01	01—02	02—03	03—04	04—05	05—06	06—07	07—08	Total.
Below 5	..	.	1		1	2	1	1	1		3		1	11
6 to 10	2	1	1	2	3	4	2	4	2		2	1	.	24
11 to 15 .. .	..	4	4	3	1	2	5	2					.	21
16 to 20	.	1	3	4	3	1	1	1	1	.			..	15
Above 21	.	4		..	1		.	.	..		..		.	5
Total ..	2	10	9	9	9	9	9	8	4	0	5	1	1	76

From this table it may be concluded that :—

(i) Gusts of 6 to 15 m. p. h are the most frequent,

(ii) Stronger gusts tend to occur during the earlier part of the night,

(iii) Gusts are comparatively rare after 03 hours.

It may be observed here that the diurnal variation of the barometer at Poona in the cold season has its secondary maximum at about 23 hrs and the secondary minimum between 04 and 05 hrs. From 20 hrs to 02 hrs the rate of change of the atmospheric pressure is small, and the barogram is almost flat during these hours. It would therefore appear that a constant pressure field is one of the conditions favourable to the occurrence of solitary gusts.

3. **Characteristics of Solitary Gusts.**—Photographs of a few typical solitary gusts are given in the Plate, in order to illustrate their chief characteristics, and the

abrupt change of direction with which their onset is invariably associated is noteworthy. The most remarkable fact about them is that they are essentially different from gusts attaining the same velocity in steady winds, in being devoid of oscillations of wind force, although they last for a period which is considerable when compared to the usual interval between successive gusts and lulls in the latter. There are however a few instances where, after reaching the maximum, the gust shows slight fluctuations of velocity before subsiding, and, on these occasions, the termination of the gust was not followed by a calm, but by a very feeble wind from the easterly direction which continued for some time. Such cases have been indicated by asterisks in the Appendix.

4 **Temperature and Pressure Changes associated with the Solitary Gusts.**—The figures in columns 8 and 9 of the Appendix give the temperature changes immediately after the occurrence of the gust and a few minutes later, when the air has attained a steady temperature. These were picked up from the records of a Casella thermograph exposed near the anemometer. It is found that in all except two cases, in which a measureable temperature change was observed, a fall of temperature amounting sometimes to about 4° F. is observed, but after the passage of the gust, the temperature rapidly rises, often above its value before the onset of the gust. These changes are important inasmuch as they throw considerable light on the origin of these gusts.

The values of the changes of pressure tabulated in column 12 of the same table have been obtained from measurements of barograms of the corresponding days. Even with a scale magnification of $\times 5$, the changes were too small to be estimated correctly by the eye unaided, and so, the traces were measured under a low-power travelling microscope, and the corresponding values reduced to inches of mercury. At the onset of the gust, the barogram almost invariably indicated a slight rise of pressure which was maintained afterwards. It is also important to notice here, that, in this respect also, the phenomenon described is dissimilar to other phenomena such as line squalls, the change in pressure due to which is generally transitory, the pressure returning to its original value, or almost to it, when the squall has passed.

The measurement of the rise of pressure is quite straight-forward when it rises from a steady value, but it is a matter of some difficulty and probably also of some uncertainty when the rise happens to occur at a time when the barometer is rising or falling on account of diurnal variation. In such cases, the measurement was made in the following manner :—The trend of the curve before the occurrence of the change was produced, and the distance between this and the trace measured parallel to the time-lines on the chart as nearly as possible at the instant of termination of the gust. The barometric tendency at the time of occurrence of the change is indicated in column 10 of the table.

In all the cases in which the period of rise of pressure was well-defined, it was found that this was equal to the duration of the gust within errors of estimation.

It should be mentioned here that the pressure changes so found will be to some extent affected by the lag of the barograph, the tendency being always to give slightly too low values of pressure change. The effect of this source of error on the quantitative estimates obtained will be discussed later.

5. **Theory of the Solitary Gust Phenomenon.**—There are three alternative hypotheses as to the cause of this phenomenon :—

(i) the upper winds breaking down to the level of the anemometer head,

(ii) the effect of waves in a surface of discontinuity, the height of which above ground level is of the order of the amplitude of the waves,

(iii) an effect in the atmosphere, not dissimilar to a " bore " in a tidal estuary, being caused by the katabatic winds acting against the seasonal pressure gradient but determined to a large extent by the local topography.

Recrudescences of wind of the nature of the gusts described above were observed by Dr. Simpson[3] in the Antarctic and were attributed by him to momentary incursions of an upper current forcing its way under a steady lower current and lifting it above the level of the recording instruments. He found that the temperature records supported this idea. In the present instance, however, it has already been shown by the author in a previous note[4] that there is a very stable pool of cold air near the ground, which the katabatic flow is unable to disturb ; it is improbable, therefore, that an upper current could work its way through an inversion layer and sweep away the stagnant air near the ground. Further, the fall of temperature observed at the onset of the gust cannot be reconciled with what should be expected when potentially warm air from above comes down to the level of the instrument. Thirdly, examination of the pilot balloon trajectories of the following mornings shows that while the direction from which the gust proceeds is between 300° and 340° in most cases, the upper winds are variable within much wider limits, so that little association could be found between the two.

The anemograms showing katabatic movements at Poona are suggestive of wave motions in the atmosphere, which, as A. H. R. Goldie[5] has pointed out, can affect surface movements when the height above ground of the discontinuity at which the waves develop is comparable to the amplitude of the waves. With the seasonal air movements consisting of a northerly current superposed over a shallow easterly drift of air, it might plausibly be argued that the recorded winds are the effect of Helmholtz waves in the surface of discontinuity between the two currents. This hypothesis fails likewise to account for the exceedingly constant direction from which the winds occur ; for, the day to day variations of the force, direction and depth of these currents are so large as to give little support to the idea that the nocturnal winds at Poona are merely wave effects. The fact that the three directions from which these winds occur are also directions of river valleys in the neighbourhood is very significant in favour of the third hypothesis.

We will now proceed to show that not only does this hypothesis successfully explain all the associated phenomena, but it also yields changes of pressure of about the same order of magnitude as would be expected from theoretical considerations. As has been stated already, the normal pressure gradient for the season in which these solitary gusts occur is feeble, and requires a wind with a prominent easterly component for balance. The katabatic winds occur from the opposite direction and tend to set up pressure gradients opposing the seasonal gradient, with the result that the kinetic energy of the winds is converted into potential energy of pressure lower down the valley. This process, as has been pointed out by Margules[6], should ultimately result in some sort of wave action. As soon as the katabatic winds weaken and are unable to maintain the pressure gradients established by them, the potential energy is reconverted into the kinetic energy of air-motion, and this manifests itself as a front of pressure discontinuity travelling up the valley with considerable velocity.

Alternatively, we could imagine, following Hann[7], that the katabatic movements are originated and maintained by a downward inclination of the isobaric surfaces along the valley slope set up by local radiative cooling during the night*.

*According to R. Wenger (*Met. Zeit.*, 1923, p. 199) it is rather the isosteric surfaces which are distorted upwards in the neighbourhood of the hill-slope (*cf.* also V Bjerknes, *M. W. R.*, Washington, 1900, p. 439) ; but owing to the air movements set up and the consequent accumulation of mass at the foot of the valley, the isobaric surfaces should also be markedly distorted there.

If on any account this circumstance disappears or its effectiveness diminishes, the isobaric surfaces straighten themselves out, an upward movement starting from the end and travelling up the valley. This is manifested as a progressive pulse of pressure increase following the same direction.

On this hypothesis, the rise of pressure occurring with the gust and its continuance at the same value even after the gust has passed are obvious consequences. The structure of the gust also is according to what should be expected from theory; for, what is recorded is not a " wind " in the usual sense of the word, but rather a pressure wave moving past the instrument with the recorded velocity much in the same way as a " tidal bore " advancing up the estuary of a river. The extent of the moving zone of disturbance as it passes over Poona is approximately equal to ½ (velocity of gust × time taken by it to pass) and is found to vary from 3 miles to 90 yards, the most frequent values, however, being less than 1 mile.

The direction from which the gust proceeds is the direction of the valley, and the gusts appear therefore to be determined by the direction of the valley than by that of the seasonal pressure gradient which, as has been shown already, is more largely variable. On our hypothesis, the normal gradient would simply serve to store up part of the kinetic energy of the katabatic movements, and have no further part to play in directing its expression afterwards. This is what one would *a priori* expect from the fact that in katabatic movements, the isobaric and isosteric surfaces over the valley only are appreciably affected.

The fall of temperature at the onset of the gust is also easily explained; it is the surface air that is transported with the passage of the front, from some distance to the east of Poona, and as it is likely to have been much less subject to the disturbing effects of the katabatic movements, it should be slightly colder than the air over Poona. The passage of the gust, however, stirs up the air rather vigorously, and a rise of temperature is the result.

6. **Comparison of Theory with Observation.**—Margules has shown from considerations of potential energy in a field of pressure, that for a mass of air moving horizontally without friction in a steady field under adiabatic conditions, the kinetic energy per unit mass is given by the expression :

$$\tfrac{1}{2}\,(G^2-G_0^2)=C_p\,(T_0-T)=C_p\,T_0\left[1-\left(\frac{p}{p_0}\right)^{R/C_p}\right] \quad . \quad . \quad . \quad . \quad (1)$$

where G is its initial velocity at pressure p in the field, G_0 its velocity at pressure p_0 and T, T_0 the corresponding temperatures, R the gas constant and C_p the specific heat of air at constant pressure. If, as in the present case, p_0-p is small, the above equation reduces to the simple approximate form ·

$$\tfrac{1}{2}\,(G^2-G^2)=RT_0\,\frac{p_0-p}{p_0}=\frac{p_0-p}{\mu_0} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where the symbol μ_0 stands for the density of air and is equal to RT_0/p_0. If it is assumed that the air is initially moving with velocity G against the gradient, then its velocity will fall to G_0 when it moves from isobar p to isobar p_0 without friction, where the four quantities, G, G_0, p, p_0, are related by equation (2). So long as the terminal pressures p and p_0 are the ame, the actual pressure *gradient* is immaterial. Frictional forces, which undoubtedly should play a large part in determining the maximum velocity of the gust as it progresses up the valley, will be insignificant for the short interval it takes in passing over Poona, and its intensity *at* Poona may

be assumed to be conditioned by the recorded change of pressure at the passage of the gust according to equation (2) above. Conversely, we can calculate the pressure difference $p-p_0$ which will be generated by a rise of wind speed from calm to G, where p and p_0 are the initial and terminal values of the pressure.

With the value $\mu_0=0\cdot00117$ for the normal conditions of pressure and temperature at night during the cold season at Poona, the pressure change according to the above formula, for each of the gust velocities tabulated in the Appendix was calculated and is entered in column 11 of the table. The corresponding pressure changes observed from measurements of the barograms were converted into millibars and given in column 12 It will be observed that the figures in these two columns are of the same order of magnitude.

Margules has further shown that, when the field is variable, equation (2) above is obtained in the form :

$$\tfrac{1}{2}\,(G^2-G_0^2)=RT\frac{p_0-p}{p_0}+\frac{RT}{p_0}\int\frac{\partial p}{\partial t}\,dt \quad . \quad . \quad . \quad (3)$$

Thus, if a mass of air is flowing towards a place of low pressure, and at the same time, the pressure at every point of its path is changing with time, then with rising pressure the increase of kinetic energy of the moving mass will be greater than it would be in a steady field, but with falling pressure, the increase in kinetic energy will be less[5]. We should accordingly expect in our case, remembering that we are dealing with movements *against* the existing gradients, the computed value to be less than the observed with a rising barometer and *vice versa*. Thus from equation (3)

$$\frac{p_0G^2}{2RT}-\triangle p=-\int\frac{\partial p}{\partial t}\,dt.$$

or

$$\triangle p\ (cal.)-\triangle p\ (obs.)=-\int\frac{\partial p}{\partial t}\,dt.$$

where $\triangle p\,(cal.)=p_0\,G^2/2RT$ is the value of pressure-change calculated on the assumption that the barometer is steady, $\triangle p$ (*obs.*) is the actual pressure-change in a field in which the barometric tendency is given by $\partial p/\partial t$ and the negative sign in the right-hand side arises owing to the fact that we are considering movements against the gradient. Thus we have schematically :

	Pressure-change. (Cal. *minus* Obs.)
Barometer steady, $\partial p/\partial t=0$	*nil.*
Barometer rising, $\partial p/\partial t$ positive	negative
Barometer falling, $\partial p/\partial t$ negative	positive

That this is more or less the case, is shown by the following :

Assuming an uncertainty of 0·05 mb. either way on account of uncertainties of measurement, the discrepancies between the computed and *observed* values of pressure change have been classified for entry in the table below according as they

are negligible, too high or too low, and according as they occur with the barometer steady, rising or falling.

	Bar steady.	Bar rising.	Bar falling.
Cal.—Obs. negligible	16	7	7
Cal.—Obs. positive	10	3	9
Cal.—Obs. negative	1	5	3

It should be remembered while interpreting this table, that the indications of a barograph are always subject to a certain amount of lag, the effect of which, with the steady barometer will be to increase the number of positive discrepancies as compared to the negative · With a rising barometer, however, the effect of lag will be to increase the number of cases with negligible discrepancies at the expense of the negative and with a falling barometer positive discrepancies will be emphasised. The above table shows these characteristics to a certain extent, so that it appears safe to conclude that what may be termed the *isallobaric effect* on the gust velocity is also discernible.

It has been mentioned early in this paper that there are a few instances where the solitary gust has occurred at the termination of the sea-breeze at Poona. Whenever a feeble gradient is disturbed by the setting up of a local circulation, one should expect a restoration of the original gradient when the disturbing forces cease to act ; and when this requires the reversal of the forced gradient, conditions seem to favour the occurrence of a solitary gust. The anemogram reproduced in Plate V of Scientific Notes, Vol IV, No 41[9] which relates to the sea-breeze at Karachi, shows a well-marked solitary gust, and it will be seen there also, that the gust proceeds from the quarter directly opposite to that of the breeze Further, the author is given to understand that the same phenomenon is associated also with the sea-breeze at Madras A few data of the gust velocities and the associated pressure changes picked from the self-recording charts of that station, kindly supplied by Mr. B. G. Narayan, show about the same order of quantitative agreement with the relation established by equation (2).

In conclusion, the author wishes to express his thankfulness to Dr. K. R. Ramanathan and Dr. L. A. Ramdas for helpful criticisms.

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APPENDIX.

Date.	Time I. S T.	Duration. Min.	Max. Vel. (m.p.h.)	Direction (W=90°) from	to	change	Temp. change. Onset (°F)	Final (°F)	Bar tendency. (mb.)	Pressure change. Cal. (mb.)	Obs. (mb.)
1	2	3	4	5	6	7	8	9	10	11	12
1929											
Nov. 6 ..	2035	..	24·0	25	205	180	—2·0	..	..	0·67	—*
7 ..	2125	5	13 0	190	305	115	—1·4	+0 8	.	0 20	—
8 .	2310	20	18·0	120	300	180	—2 0	+0 4	..	0 38	—*
18 ..	2335	3	22 0	125	315	180	—1·6	+3·2	..	0·56	—*
20 .	2325	15	10 0	130	310	180	—0·8	+0·5	0	0 12	0 12
29 ..	0330	20	5·5	350	180	170	—1 0	+1·4	0	0·04	0·03*
Dec. 4 ..	0456	11	3 0	135	338	157	—0 8	..	+	0·01	0·29
9 ..	2235	5	16 0	140	310	190	—2·5	+5 0	0	0 30	0 06
10 ..	2205	15	16 0	158	330	172	—2·4	+3 8	0	0·30	0 28*
15 ..	0300	7	7 0	135	315	180	—0 5		—	0 06	0·14
18 ..	0132	3	12 0	135	322	173	—1 8	+1·6	—	0·17	0·09
26 ..	2157	3	14 0	162	342	180	—1 0		0	0·23	0 18
27 ..	2205	3	16·0	68	315	113	—1 2	.	0	0·30	0·20
28 ..	2048	2	22·0	144	327	183	—1 4	+1 6	+	0·56	0·30
1930											
Jan. 3 ..	0138	3	13·5	140	315	175	—1 2	+1 5	..	0 20	—
6 ..	2115	5	5 0	105	280	185	..	..	..	0·03	—
9 ..	0012	8	12 0	45	315	90	—3 2	—3·2		0 17	—*
15 ..	0048	2	3·5	215	40	185	—0 8	..	..	0 01	—
24 ..	2345	7	4 0	130	310	180	..		.	0 02	—
Mar. 5 ..	2354	7	10·0	130	310	180	—2 2	+1 2	..	0·12	—
6 ..	0028	2	4·0	266	98	168	—2 0	..	.	0 02	—
14 ..	0615	5	6·0	135	315	180	—3·2	+0·6	..	0·05	—
26 ..	0155	5	12·5	130	320	170	—4·2	+0·8	..	0·18	—*
" ..	0535	5	8·0	100	285	185	—2·0	+0·4	.	0 08	—
Oct. 6 ..	0018	3	8 0	115	295	180	..	..	..	0·08	—
Nov. 6 ..	2044	2	18·0	160	325	165	—0 6	+0·6	0	0 38	0·28
7 ..	2018	6	9·0	160	340	180	—2 8	+1·2	+	0·09	0·21
8 ..	0715	5	4·5	180	315	135	..	..	+	0 02	0·00
" ..	1945	5	9·0	188	15	187	—1·8	+0·8	+	0·09	0 19
10 ..	0020	3	7·0	150	325	185	+0·4	..	—	0·06	0·08
10 ..	2025	5	14·0	160	315	205	—1·6	+2·0	0	0·23	0·23*

* See page 3.
0 means steady barometer : + means rising barometer ; — means falling barometer.

Date.	Time I. S. T	Duration. Min.	Max Vel. (m p h)	Direction (W=90°) from	to	change	Temp. change Onset (°F)	Final (°F)	Bar tendency. (mb.)	Pressure change. Cal. (mb.)	Obs. (mb.)
1	2	3	4	5	6	7	8	9	10	11	12
1930											
Nov. 11	2240	5	19 0	162	315	207	—0 4	+2·6	0	0 42	0·17*
"	2215	3	13 0	120	320	200		..	0	0 20	0·12
12	2255	5	8 0	120	315	195		..	0	0·08	0·13
13	2115	3	11 0	150	320	190	—0 4	+0·8	0	0 23	0·22
14	2005	5	14 0	158	330	188	+2 4	.	+	0 23	0·16
15	2045	5	12 5	230	345	115	—2 8	+1·4	+	0 18	0·14
16	2159	6	20 0	135	315	180	—1 6	+0 7	0	0 47	0·16
23	1926	2	9 0	198	315	117	—0 6	..	+	0·09	0·09
24	0010	4	17 0	125	300	185	—0 8	+0 8	—	0 33	0·08
"	2230	6	13 0	190	315	125	—1 4	+0 6	0	0 20	0·20
Dec 11	0205	5	6 0	130	315	185	+0 4		—	0 05	0·11
	0217	3	8 0	150	330	180	—0 1	..	0	0 08	0·09*
"	0230	2	5 0	115	300	165	—1 2	..	+	0 03	0·07*
16	2323	12	9 0	130	315	175	0 8	+0·4	—	0 09	0·14
18	2150	8	7 0	120	310	190	—0 6	..	+	0 06	0·13
19	2039	3	11 0	165	342	177	—2 8	+1 0	+	0 23	0 18*
22	2008	4	20 5	200	340	140	—4 0	+2 8	0	0 49	0·30
23	2153	4	15 5	145	330	175	—3 2	+5·4	0	0 28	0·27*
1931											
Jan 2	2156	6	16 4	135	320	175	—4 2	+3 0	0	0 31	0·19
3	0540	5	5 4	125	3'5	145	—1 0	+0 7	+	0 03	0·08
"	2032	8	20 8	135	315	180	—1 8	+4 0	0	0 47	0·38
4	2115	5	15 4	165	335	170	—4 2	+2·6	0	0 29	0·29
5	0545	1	3 2	310	135	175	—1 8	.	+	0 01	0·04
"	2342	8	16 0	135	315	180	—2 0	+1·8	—	0·30	0·12*
6	0015	4	12 0	160	320	160	—0 6	+0 8	+	0·17	0·00
7	0142	8	14 0	135	315	180	—1 0	..	—	0·23	0·16
10	0247	8	13 2	130	290	200	—1 0	..	—	0 20	0·14
12	0250	3	9·0	150	325	175	..	..	—	0·09	0·13
"	2328	2	19 0	125	325	170	—1 2	+2·8	—	0·42	0·17
13	2245	5	14 0	280	165	115	—3·8	+2·4	0	0·23	0·14
17	0035	5	13 4	162	340	178	—2·0	+1·8	0	0·21	0·30
20	0128	4	21·4	135	320	175	—0·8	+1·0	—	0·53	0·19

* See page 3.
0 means steady barometer ; + means rising barometter ; — means falling barometer.

Date.	Time I. S. T.	Duration. Min.	Max. Vel. (m.p.h.)	Direction (W = 90°) from	to	change.	Temp. change. Onset (°F)	Final (°F)	Bar tendency. (mb.)	Pressure change. Cal. (mb.)	Obs. (mb)
1	2	3	4	5	6	7	8	9	10	11	12
1931.											
Jan. 17 ..	0250	12	16 0	45	225	180	—1·4	+1·2	—	0·30	0·27
21 ..	2208	6	6·4	112	300	172	..	.	0	0·05	0·07
26 ..	0021	7	6 0	140	315	175	..	..	—	0 05	0·08
27 ..	0256	6	7·0	203	292	89	..	..	—	0·06	0·10
Feb. 8 ..	0355	8	4·0	105	285	180	..	..	0	0 02	0·07
11 .	2303	3	8·4	30	318	72	..	.	0	0 08	0·10
12 ..	0233	7	14·5	125	310	175	—1·4	+0·5	—	0 25	0 20
,, ..	0540	2	4·6	15	190	175	..	..	+	0 02	0·13
19 ..	0140	15	9·4	115	310	165	—0·2	..	0	0·11	0·11
,, ..	0155	10	11·4	315	15	60	..	..	—	0·15	0 08
20	0115	17	10 0	5	182	183	..	.	0	0·12	0 14*
21 ..	0144	2	4 6	37	175	138	—0 5	..	—	0·02	0·09
,,	0340	6	19·0	105	285	180	..	.	..	0·42	0·21*

* See page 3.
0 means steady barometer; + means rising barometer ; — means falling barometer

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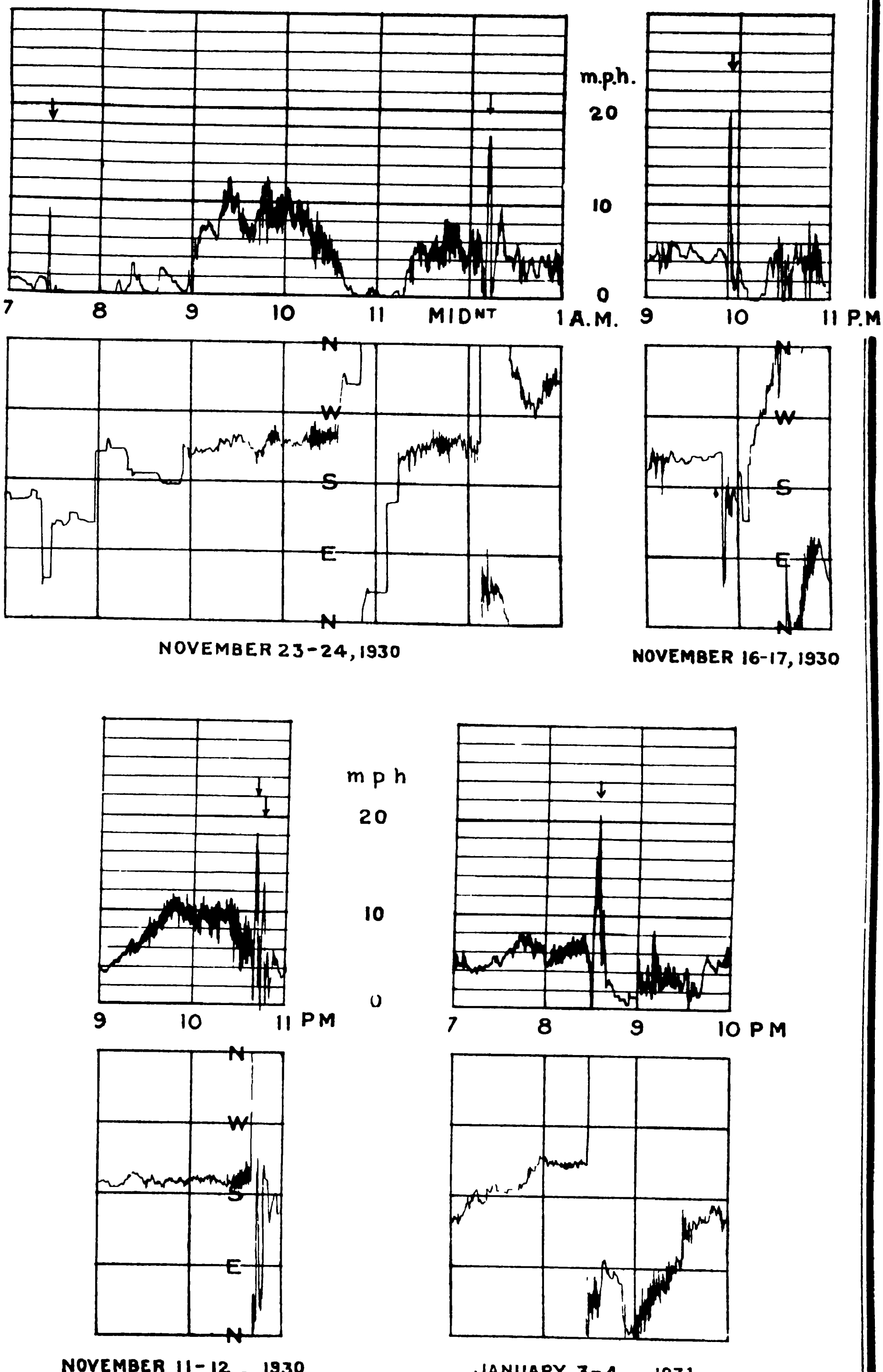

Plate 1. Four typical instances of solitary gusts.

Offset, G P Z O 1932

INDIA

METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

Vol. IV, No. 45

The method of coincidences, or a quick method of determining the approximate value of a simple correlation co-efficient.

BY

S. R. SAVUR, M.A., Ph.D.

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THE METHOD OF COINCIDENCES, OR A QUICK METHOD OF DETERMINING THE APPROXIMATE VALUE OF A SIMPLE CORRELATION CO-EFFICIENT.

BY

S. R. SAVUR, M.A., PH.D.

(*Received on 15th November 1931.*)

In a recent issue (1) of the Quarterly Journal of the Royal Meteorological Society, the author described in brief a quick method for finding the value of a simple C. C. (correlation co-efficient) and indicated there that further details would be published elsewhere.

The method as already described consists in preparing a punched slide for each set of data that enables one very rapidly to count the number of agreements and disagreements of sign between any two sets of data. By making use of a table given by Sir G. T. Walker and E. W. Bliss [page 77 of (2)] the approximate value of the C. C. is then readily calculated. The method is very useful when we have a large number (say more than 15) of simple C. C.'s to evaluate. But when we have a smaller number of them the following variation of the method will be found very handy.

In one column out of two on a strip of ruled paper we enter the order (or the year) of the departure from the mean of a factor and in the adjoining column the corresponding sign of the departure, a zero departure being entered "0". A similar slide is prepared for another factor, the C. C. of which with the first is to be determined. The two slides are placed one over the other so that the columns for the two factors containing the signs are side by side with the corresponding signs in the same horizontal line. The number of agreements in sign (zeros excepted) is counted. The number of zeros in both is also counted up separately, two corresponding zeros being, however, counted as one. The following working is self-explanatory.

Total number of departures for each factor $= n_1$

Number of agreements (zeros excepted) in sign $= n_2$

Number of zeros .. $= n_3$

∴ Total number of agreements in sign $= n_2 + \frac{n_3}{2}$

We then calculate $p = \dfrac{n_2 + \frac{n_3}{2}}{n_1}$

From this value of p the corresponding value of the C. C. is determined in the manner described in (1). The only reason why this method may be preferred to that given in (1) when the number of C. C.'s to be determined is small is that the preparation of the slides for this takes much less time than that for the other and more than counterbalances the extra time taken in calculating the C. C. by this method.

It was mentioned in (1) that the probable error* of the C. C. determined by this method is approximately 0·05 (when n_1 is not less than 55)† and that four times this

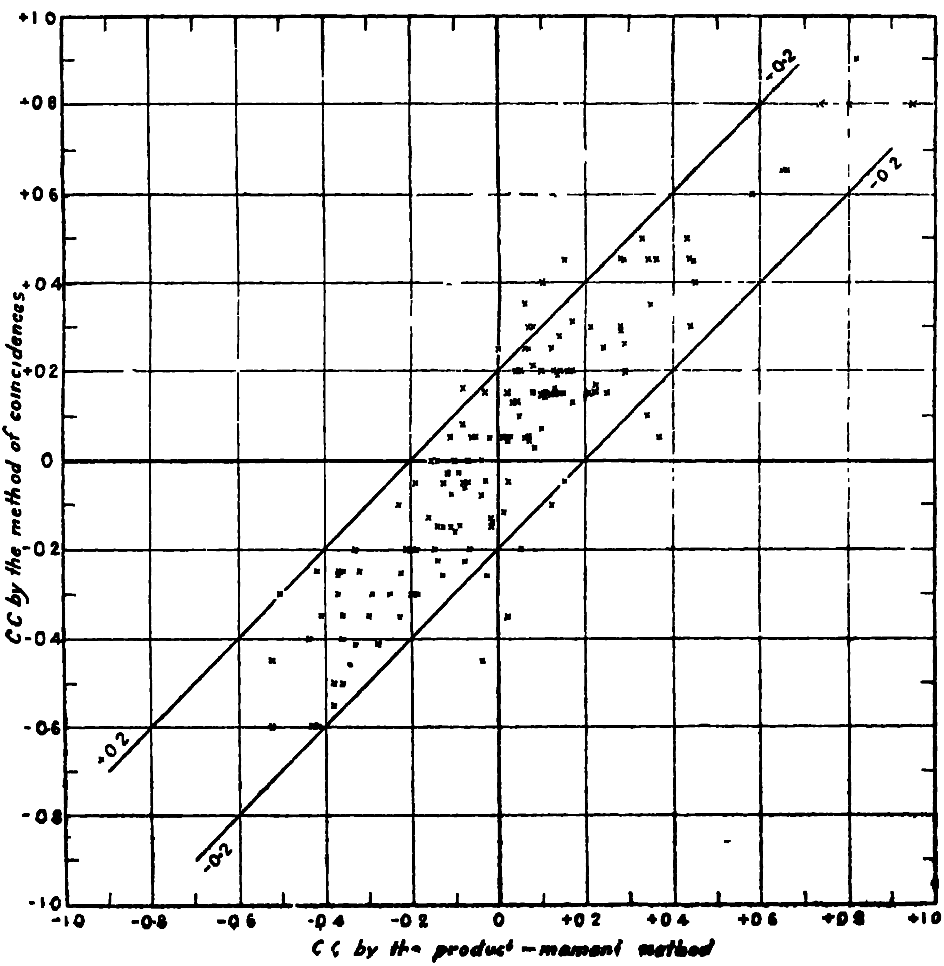
*By "error" is here meant the difference between the approximate value and the more accurate one as calculated by one of the usual methods.

†The reason why 55 was taken is that for a large number of meteorological elements reliable data are available for not less than 55 years, and as this method was developed with a view to utilise it for meteorological data, this number appeared to be suitable.

value, *viz.*, 0·2, may be taken as the limit of the error that may be expected ordinarily. It has not been possible for the author so far to determine theoretically the probable error of the C. C. obtained by this method. It can, however, be seen that the greater the n_1 is, the smaller will be the probable error, provided, of course, that both the factors obey the normal law. All that can be given here is an estimate of the probable error derived from experience. When the above value of 0·05 for the probable error was obtained, we had only 40 C. C.'s worked out both by this method and by the usual method. Since then the number of C. C.'s for which both sets of values are available has been increased to 146 and the following conclusions may, therefore, be considered more reliable.

Out of the 146 C. C.'s mentioned above, for none of which n_1 was less than 47 while for more than 120 of them n_1 was greater than 55, only 15 had an error greater than 0·2 (signs being neglected here), 87 had an error not exceeding 0·1, 72 of these having an error not more than 0·07. We may therefore roughly estimate the probable error to be 0·07 and take 0·2, three times the probable error, as the limit of error that may be ordinarily expected in this method.

The results are exhibited graphically in *Fig. 1* below. The slant lines correspond to errors +0·2 and —0·2. The region between these two lines contain C. C.'s for which the error lies between ±0·2. The very small number of C. C.'s for which the error is numerically greater than 0·2 is quite apparent.



This limit of error, 0·2, appears to be confirmed by the values given in figure 3 on page 78 of (2) by Walker and Bliss. Out of 57 values shown there only 3 have an error more than 0·2, 8 equal to 0·2, and the remaining less than 0·2. The just comparison of these with the results obtained by the author is not possible, as the value of n_1 for the former is not given in (2). On the whole, it may be said that the values obtained by these authors are in agreement with the conclusions given above and we may safely infer that when n_1 is not less than 55, the error in the value of C C. obtained by the method of coincidences is not likely to exceed 0·2 ordinarily

An approximate idea of the labour saved by the method of coincidences may be obtained from the following :—

Suppose the 146 C C.'s mentioned above have not been worked out, and we have to find out which of them are significant. Let the least significant value (numerically) be 0·5 as determined by either Walker's method (3) or a slightly more accurate one given in (4) We first find the approximate value of these C. C.'s by the method of coincidences very quickly. Since we are not interested to know the accurate values of the C. C.'s which are numerically less than 0·5, we need only to find by the usual method those C C.'s which have values not less than 0·3 as obtained by the method of coincidences This number is only 43 and by calculating more accurately only these C C.'s by one of the usual methods, we will miss none of the 9 C C.'s which are significant from our point of view

This does not, however, preclude the possibility of occasionally getting an error much greater than 0·2 even when n_1 is not less than 55 . in one of the values given by Walker and Bliss in (2) the error was as high as 0·42 , the exact value n_1 for this, however, is not stated in their paper In our case, too, there was one as high as 0·41 In such a case, it appears, we may reasonably conclude that either one or both the factors do not obey the normal law and hence that the methods of correlation are not quite suited to measure the relationship between them This conclusion has been verified in our case.

Even though the two quantities may vary according to the normal law, there still remains the possibility, very rare indeed, of getting an error much greater than 0·2. When we do get such an error, it leads to an interesting deduction regarding the true value of the C C. between the quantities

Suppose we have a universe containing two quantities of which the departures from normals obey the error law We take a random sample containing n_1 values of each. If the C C.'s calculated from this sample according to the product-moment method and the method of coincidences be r_1 and r_2 respectively, what is the chance that the true C C is r_0 ? If we can calculate this chance, the most probable value of the true C. C. is that value of r_0 for which this chance is the greatest.

Unfortunately it has not been possible to solve this so far even on the assumption that all values of r_0 are equally likely From general considerations, however, we may make the following deductions:

(1) Suppose $r_1 = r_0$, then the greatest chance is that r_2 is also equal to r_0. We do not know r_0, but when $r_1 = r_2$ we may infer that the most probable value of the true C. C. is also r_1.

(2) It is also not difficult to see that the chance of occurrence of a given error is greatest when $r_0 = 0$, becomes less and less as the numerical value of r_0 increases and becomes zero when $r_0 = 1$ (numerically). Hence when the error (*i.e.*, $r_1 \sim r_2$) is much bigger than 0·2, say, greater than 0·35 (five times the probable error), a very probable value of the true C. C. is zero, or at any rate it is very likely that the true C. C. is much different either from r_1 or r_2.

Thus in these respects the method of coincidences forms a valuable supplement to those already known in that in addition to saving a large amount of labour it enables us to judge whether a C. C. is likely to be significant or not.

By merely moving one slide over the other (prepared in connection with this method) we can also obtain the C. C. of one of the quantities with the other any number of years (or orders) earlier or later, provided, of course, the total number of elements for each of the C. C. is not less than 55. In this way a number of C. C.'s, which have been termed "symptomatische" C. C.'s by F. Baur (5), can be quickly determined. Whether any use can be made of these C. C.'s remains to be seen. Perhaps they may be useful for testing periodicities.

In conclusion, it may be said in favour of the method of coincidences, that as n_1 increases not only will the error get less, but the time in working out the C. C.'s will also become comparatively much less than with other methods, letting alone the fact that there is practically no chance of committing an error in the calculation.

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Thunderstorms in the Peninsula during the Pre-Monsoon Months April and May

BY

S. P. VENKITESWARAN, B.A. (Hons.).

(*Received on 31st October 1931.*)

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THUNDERSTORMS IN THE PENINSULA DURING THE PRE-MONSOON MONTHS APRIL AND MAY

BY

S. P. VENKITESWARAN, B.A. (HONS.).

(*Received on 31st October 1931.*)

In a previous Scientific Note*, the annual variation of thunderstorm frequency at a number of selected stations in India has been published, from which it is evident that the maximum monthly frequency of thunderstorms occurs in April in the extreme south of the country, in May in Mysore, in June in the Central Provinces, and in July in the United Provinces. Dr Desai† has recently studied the thunderstorms of Poona and come to the conclusion that they are generally associated with a superposition of northeasterly to northwesterly winds at 3 km. and above over southwesterly to southeasterly. In the present paper is presented a more detailed study of the distribution of thunderstorms in the Peninsula south of latitude 18°N, (see *Fig. 1* which shows the area in contour), and the upper air circulation favourable for their occurrence during the months April and May, with special reference to the year 1929.

The frequency of thunderstorms at 39 third class observatories in the Peninsula was worked out for the months April and May, during the ten years 1920—29, in order to find out their normal distribution during these months A station was reckoned as having had a thunderstorm on a day when there was evidence to show that there was precipitation accompanied by thunder or lightning Days on which the area was appreciably influenced by storms or depressions have been excluded. *Figs. 2a* and *2b* represent the number of days on which thunderstorms occurred during the months April and May respectively for the ten-year period 1920—29. It is evident from the figures that the places most subject to this weather are those lying near the Western Ghats and the hilly regions of Mysore. It is also found that in southeast Madras the frequency of occurrence of rain with thunder is greater in April than in May, while at all other places there is a larger number occurring in May than in April. Within the limits of the area under consideration, they also occur in lesser number during each of these months as we go to higher latitudes.

Tables I (a) and *I (b)* give the hourly frequency of thunderstorms at Bangalore and Madras, respectively, for different months of the year. The distribution during the day for Trivandrum is given in Indian Meteorological Memoirs, Volume X, p. 180. Thunderstorms occur mostly in the evenings during April and May in Madras, and there is a sharp maximum frequency at 14 and 15 hours. Thunderstorms do not occur at all in these months in the morning hours at Bangalore, and the period of maximum frequency is between 20 and 21 hours. At Trivandrum also thunderstorms occur more frequently during the evening hours in April and May, and the time of maximum frequency is between 15 and 16 hours.

* Scientific Notes, Vol. I, No. 5

† Dr. B. N. Desai. A Study of Thunderstorms in Poona in 1930, Scientific Notes, Vol. III, No. 27.

It is popularly known in Mysore and the Deccan that thunderstorms in this period are heralded by the appearance of cumulo-nimbus in the northeast. An analysis of the time of occurrence of the rain in April and May, at Bangalore and Mysore, shows that, generally, the precipitation occurs earlier at Bangalore than at Mysore, and that the thunderstorm travels from a nearly easterly or northeasterly direction. Taking into account only the time at which rain actually fell on the same day at Bangalore and Mysore, it is found that, out of 37 such occasions in April from 1920—29, during 22 occasions the rain occurred earlier at Bangalore than at Mysore. The corresponding number in May was 37 out of 59 such occasions. There was a difference in time of occurrence at the two places ranging from 2 to 4 hours. "The hot season rains in April and May, sometimes called the Mango Showers, are of the accidental kind, and give heavy short storms from the east*" It may be also mentioned that the thunderstorms occurring in Travancore generally travel from a northeasterly direction to Trivandrum†

The seasonal weather over India can be briefly stated as follows. The surface pressure gradients are generally weak during the month of April‡, but are such as to draw in air from the neighbouring seas into the Peninsula and northeast India; the heating of the land surface causes the accentuation of low pressure area during evenings. During May the gradients are stronger and a broad trough of low pressure running from northwest India southeastwards along the Gangetic Valley gets established. The isobars in the Peninsula run approximately from northwest to southeast, roughly parallel to the west coast. The winds on the surface are from south to southwest on the east coast, and from between west and northwest on the west coast. There is therefore at the surface an inflow of air from the Arabian Sea into the Peninsula. The mean monthly temperature for the Peninsula has its maximum value in April and May, and thus the moist air from the seas gets warmed up by the prevailing high temperature during these months

The mean monthly frequency of winds at 1, 2 and 3 kilometres during April and May, at Trivandrum, Bangalore, Mangalore, Madras and Poona have been published in the departmental Scientific Note§. The diagrams 3 and 4 give the normal stream lines of upper winds at the levels 1 km., 2 km. and 3 km. The most interesting feature of these stream lines is that the places of maximum occurrence of thunderstorms coincide with places where air arriving at 1 and 2 km. have travel over sea areas and are overrun at 3 km. and above by air of distinct land travel and presumably of less specific humidity. It is seen from the table and the figures referred to above that, during April, the air at the 1 km. level flowing into the Peninsula has generally a travel over the Arabian Sea It is also seen that, at higher latitudes in the Peninsula itself, the air at this level has less and less travel over sea, and would therefore become more and more dry. The wind at 2 km. during this month, below latitude about 13°N, is easterly, and therefore moist air from the Bay of Bengal is flowing over the middle and lower Peninsula, while above this latitude the wind is westerly, as is indicated by the wind at Poona, and these have comparatively a very small travel over sea, and are therefore presumably less moist. The air flowing into the Peninsula at the 3 km. level and above has no travel over sea, and it is only air of land origin skirting round an anticyclone at this level over the middle of India. There is therefore, in the south of the Peninsula, moist air of sea origin up to 2 km. during April, and above this is dry air with practically no sea travel, which gives sufficient conditions for instability for the occurrence of afternoon thunderstorms.

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* Imperial Gazetteer of India, Mysore and Coorg, page 8.

† Thunderstorms in Trivandrum, K. R. Ramanathan,—Indian Journal of Physics, Vol. VII, 1922, page 107.

‡ Climatological Atlas of India, Eliot, Plates 14, 15 and 16.

§ Scientific Notes, Vol. II, No. 17, Part D.

The conditions during May are similar to those in April, the only difference being that, during this month, the wind at the 2 km. level flowing into the south of the Peninsula has no longer a travel over the Bay of Bengal, but is similar to the winds at the 1 km. level, and has a tavel over the Arabian Sea. *Fig. 12* shows the relation between temperature and humidity with height as observed by Mr. J. H. Field from a kite flight at Belgaum on 28th May 1906, and it is evident from this that the air is moist up to 2 km. and dry above. It will be noticed that the frequency of occurrence of thunderstorms diminishes at higher latitudes, and this is due to the decrease in the moisture content in the first two kilometres. Again, taking Poona as an example, one finds that the air at 3 km. has travelled nearly completely round the anticyclone and, being also generally very weak, may not retain its original properties. It has also passed through regions where thunderstorms are of common occurrence. It may be mentioned here that the frequency of thunderstorms is greater in April than in May in southeast Madras, and this is due to the moist wind at 2 km being from the Bay of Bengal. The frequency is much greater nearer the west coast and over the regions of Mysore, and this is to a considerable extent due to the influence of the orography The Cardamom Hills to the east of Travancore, the Nilgiris and the Bababudan Hills in Mysore are at most places nearly 2 km. high, and the moist air from the Arabian Sea has a chance of getting collected to the west of these hills. When drier air is superposed on it and ground heating raises the lower layers, instability results at the surface of transition of the two layers.

The mean lapse-rates up to 2 km. during the months April and May, as observed from temperature indicators at Madras, is 5°C per km and 5·2°C per km. respectively in the morning The mean lapse-rate for May in the afternoon is 6·4°C per km. It may be mentioned that the normal values of the relative humidity at 8 A.M. at Madras, Bangalore (0·92 km.) and Kodaikanal (2·5 km.) for April are 76%, 67%, and 63% respectively, and 66%, 72% and 68% respectively for May, showing that the air has nearly the same moisture content up to 2 km. over the south of the Peninsula.

It has been already mentioned that the source of the air at the 3 km. level over the Peninsula, including Poona, during April and May can generally be traced back to northwest India The mean temperatures of the air at 3 to 5 km. in May are practically the same at Agra and Poona, while in April the Agra temperatures are lower by about 2°C. The mean normal value of the dry bulb temperature at 16 hrs. in May at Madras is 91°F (306°A), and, assuming the afternoon lapse-rate of 6·4°C per km., one finds that on the mean there is no definite temperature contrast between air at Madras and Agra at 3 km. On individual days, when there is a rapid flow of air from north India towards the south, there may be a difference of temperature, but with the data available at present, it is not possible to be precise on this point.

On charting the rainfall recorded at all the provincial rainfall stations in the Peninsula south of latitude 18°N for every day in April and May 1929, it was found that the rainfall was neither scattered nor local as one might infer f om the data from the daily weather reporting stations alone, but was often widespread; the number of occasions when there was scattered and local distribution of rain was small. It was however found that isohyets could not be drawn, and the distribution of the amount of rain was irregular. Trajectories of the wind at 1, 2 and 3 km. above sea level at Trivandrum, Managalore, Bangalore, Madras and Poona were also drawn for a large number of days in April and May 1929.

Figures 5 to *8* show the upper air trajectories in the morning of a number of selected days and the corresponding rainfall distribution during the next 24 hours, (8 hrs. to 8 hrs.).

Figure 5:—*7th May 1929.* The trajectories of air arriving at Poona show that there could be very little moisture in the first two kilometres and the air at 3 km. was very weak and indefinite. The trajectories for Trivandrum show that the air was from the Arabian Sea at all levels and as such instability could not be expected there. When we compare the trajectories for Madras, Bangalore and Mangalore, we find that at Madras the wind at 2 km. was distinctly of land origin and therefore dry, and there was moist air only up to 1 km. But there was moisture up to 2 km. directly from the sea at Mangalore, and the trajectory at 2 km. for Bangalore indicates the limiting area up to which there is moisture up to 2 km. All the three places have dry land air at 3 km. The trajectories at 4 km are found to be similar to those at 3 km. *Fig. 5b* shows the area at which rainfall occurred during the day. The relation between the air masses over an area up to 4 km. and the thunderstorm rainfall over the area appears to be very striking.

Figure 6:—*25th May 1929.* The air up to 2 km. at Poona is more directly from sea on this day, but the air at 3 km. also was from the Arabian Sea, and as such one can hardly expect any rain over that region.

Figure 7,—*27th May 1929* is another striking example which shows the relation between the area of rainfall and the air masses over the area

In *Fig. 8*, 8th April 1929, the air at 1 and 2 km., as indicated by the trajectories at Bangalore and Madras, is from the Indian Ocean or from the south Bay At Poona and Mangalore, the air at 1 km. is from the Arabian Sea, while that at 2 km is from the Bay of Bengal. The air at 3 km. at all these places is of land origin One finds on this day a very wide distribution of rain, and orography had a large influence in its occurrence.

In *Fig. 9*, 9th May 1929, the air is from the north at both 1 and 2 km levels, and therefore there is not sufficient moisture in the lower levels for the formation of thunderstorm though the air at 3 km. may be of land origin, as is usually the case. In *Fig. 10*, 14th May 1929, the air at Madras was coming from west at 1 km. At Bangalore the air is of Arabian Sea origin at 1 km., but that at 2 km has only land travel; the air at 3 km. is not the usual one of land origin, but flows in from the Arabian Sea. At Mangalore, though there is moisture in the first two kilometres from the Arabian Sea, the air at 3 km. is also from the Arabian Sea, and as such thunderstorms did not occur in those areas.

Figure 11:—*20th May 1929.* Scattered distribution of rain sometimes occurs during certain thunderstorms, and this is well illustrated by *Fig. 11* where the moist air at 1 km. or 2 km. is nearly stagnant and the winds are very weak.

In a paper* published a few years ago, Dr. Ramanathan pointed out that the thunderstorms at Trivandrum are most frequent during seasons when there is a great frequency of calms at about 2 km., as given by the winds at Agustia (nearly 6,200 ft. above sea level), thus facilitating upward convection. The winds at Trivandrum during May up to 2 are mainly westerly to northwesterly, and the winds at 3 km. are northwesterly or northerly to northeasterly. It is observed from the analysis of the thunderstorms in April and May 1929 that, if the winds are northwesterly up to 3 km., there was seldom any precipitation produced. (See *Figs. 5, 6, 10* and *11*.)

Thunderstorms therefore occur when there is a moist westerly or northwesterly air up to 2 km. and a northeasterly current at 3 km., having only a travel over land. Their occurrence is also very much facilitated by the orography. To the east of Cochin are the Anamalais with an average height of nearly 2 km., and moist air gets entrapped in the coastal regions and, on being lifted up, owing to the difference in

* *Loc. cit.*

the lapse-rates, gives rise to the instability. West of the Ghats the inflow of moist air is vigorous in the evenings on account of the sea breeze and, with the high barriers to the east, thunderstorms are of more frequent occurrence in the Cochin and Travancore areas.

The thunderstorms of the Peninsula present points of similarity to the Nor'westers of Bengal*. As has been already mentioned previously, they have a tendency to travel in the direction of the overrunning dry air at 3 km. These thunderstorms are not so vigorous as the Nor'westers of Bengal, for the dry air at 3 km. and above loses much of its velocity in skirting over the region of high pressure in the central parts of India and the Deccan, and has also to travel over a larger extent of land towards lower latitudes before it reaches a region where there is a regular supply of moisture in the lower layer. Its properties therefore gradually approximate to those characteristic of the new environment. In Bengal, there is a large quantity of moist air entering the country direct from the Bay, on account of the prevailing pressure distribution. Superposed on this, there is often dry cool air at 3 km. and above, of land origin coming from the Punjab, more or less parallel to the Himalayas. The movement being rapid and along a latitude, the original temperature and dryness are more likely to be retained.

I am much indebted to Dr. K. R. Ramanathan for his encouraging interest in the work I am also indebted to Mr. C. Seshachar of Bangalore and Mr. A. A. Narayana Iyer of Madras for giving me the data of hourly frequency of thunderstorms at Bangalore and Madras respectively.

* Thunderstorms of Calcutta, 1900-26, V. V. Sohoni, Scientific Notes, Vol. I, No. 3.

TABLE I a.

Mean hourly frequency of thunderstorms at Bangalore for the years 1920—29.

Hours.→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Time of occurrence not available.	Total.
January ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1	0·2	0·3	0·4	..	..	..	1·0
February ..	..	..	..	..	0·1	..	.	..	..	..	..	..	..	..	..	..	..	0·2	0·1	0·3	0·1	..	0·1	..	..	1·0
March ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·2	0·3	.	0·3	2·0	0·2	0·4	..	..	0·5	3·9
April ..	0·1	0·2	..	..	..	..	..	..	..	..	..	..	..	0·3	0·4	1·0	1·1	1·5	1·4	6·0	4·0	2·0	0·1	0·1	0·7	18·9
May ..	..	..	..	..	..	..	..	..	..	..	..	..	0·2	0·9	2·1	1·1	1·6	1·5	1·7	5·6	4·0	1·5	0·9	0·4	0·3	21·8
June ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1	0·6	0·7	0·6	1·0	2·8	2·6	0·6	0·5	0·1	0·4	10·0
July ..	..	..	..	..	..	..	..	..	..	..	..	..	.	0·2	0·2	0·3	0·2	0·1	0·2	1·5	0·8	0·1	0·1	.	0·1	3·8
August ..	..	..	0·1	..	..	..	..	..	..	..	..	..	..	..	0·1	0·5	0·6	0·3	0·3	1·5	0·9	0·5	0·3	.	0·4	5·5
September ..	0·1	0·1	0·1	..	..	..	..	.	..	.	..	..	0·1	..	0·3	0·3	0·9	0·7	0·8	4·1	2·7	1·3	1·0	0·3	0·3	13·1
October ..	..	..	..	..	..	..	..	..	..	0·1	..	..	0·1	0·2	0·2	0·8	0·7	0·5	1·7	3·5	1·3	0·9	0·4	0·4	0·2	11·0
November ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1	0·1	..	0·1	0·3	1·1	0·8	0·6	0·1	..	0·3	3·5
December ..	..	..	..	..	..	..	..	.	..	..	..	..	.	..		..	.	.	0·3	0·2	..	1·0	.	.	..	0·6

TABLE I b.

Mean hourly frequency of thunderstorms in Madras during each month of the year as deduced from records from 1916—1930.

Hours.→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total.
January ..	.	..	..	..	..	.	..	.	0 07	..	..	..	..	0 07	..	0 07	..	..	.	..	..	..	..	..	0·21
February ..	..	..	0 07	..	..	..		0 07	.	..	..	..	..	..	..	..	..	..	..	0 07	..	..	..	..	0 21
March ..	..	..		..	0 07	..	0 07	..	..	0 13	..	0 07	0 13	0 20	0 07	0 07	..	..	..	..	..	..	0·07	..	0 81
April ..	..	..	0 07	0 07	0 13	0 13		0 07	..	0·13	0 20	0 07	0 40	0·13	0 20	0 07	..	..	0 20	0·13	.	.	..	.	2 00
May ..	..	0·07	0 20	..	..	0 20	0 07	0 07		.		0·33	0 33	1 20	1 07	0 27	0·47	0 53	0 13	..	.	0 07	0 13	0 07	5 21
June ..	0 13	0 13	0·07	..	.		0 07				0 07		0 13	0 67	1 13	1 00	0 87	0 60	0 67	0 40	0 07	0 13	0 27	0 07	6 48
July ..	0·20			0 20	0 13	0 13	..	0 13		.	0 07		0 27	0 20	0 67	0 60	0 53	0 93	0 53	0 73	0·33	0 07	0 27	0 20	5·99
August ..	0·03	0 02	.	0 20	0·20	.	0 13	0 07	0 07	0 07	0 07	0 20	0 33	0 67	0 53	1 53	0 67	0 67	1 00	0 60	0 53	0 20	0·20	0 07	8 34
September ..	0·13	0 20	0 13	0 27	0 40	0 20	0 33	0 33	0 07	0 13		0 53	0 47	0 67	1 33	0 47	0 73	0 53	0 80	0 33	0 07	0 20	0·40	0 33	8·93
October ..	0 20	0 40	0·27	0·60	0 20	0 07	0 40	0 60	0 33	0 67	0 33	0 53	0 53	1 33	0 93	0 67	0 53	0 33	0 27	0 20	0 47	0 07	0 07	0·27	10 27
November ..	0 20	0·20	0·27	0·27	0·27	0 20	0 33	0 27	0 20	0 33	0 13		0 40	0 40	0 20	0·13	0·27	0 13	0 27	0 07	0 13		..	0 07	4·74
December	..	..	..	..	..	.		0 20	..	0 07	.	0 13	0 07	0 07	0 20	.	0·07	..	0·07	..	..	..	..	..	0·88

M37DGofOb—360—17-8-32—GIPS

The Peninsula below latitude 22°N shown in contour.

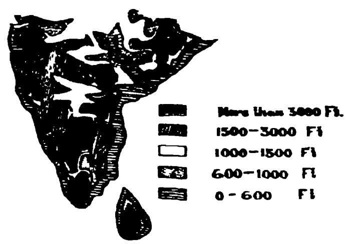

Fig 1

April

Fig. 2 a

May

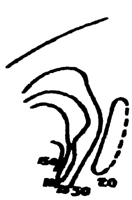

Fig. 2 b

G P Z O POONA, 1932

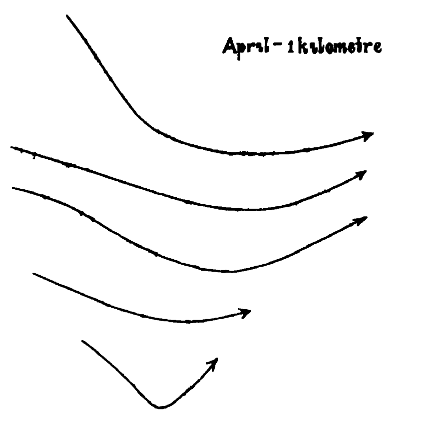

Fig 3a

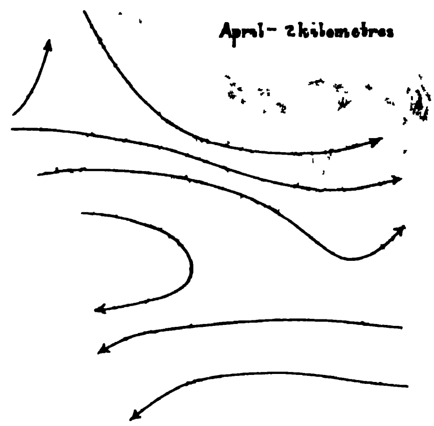

Fig 3b

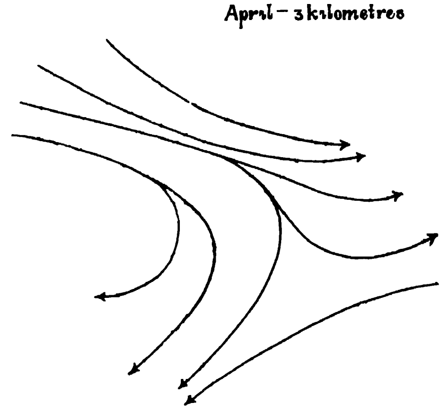

Fig 3c

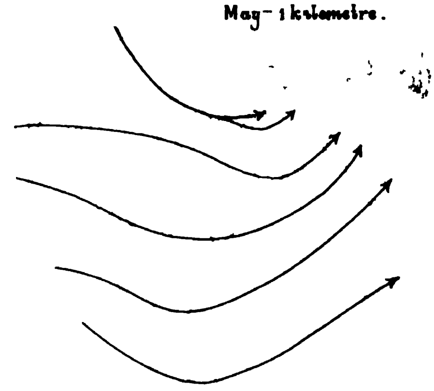

Fig 4a

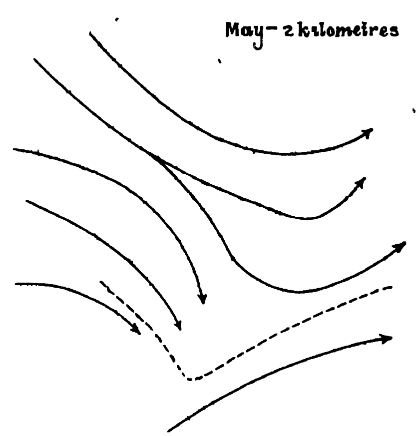

Fig 4b

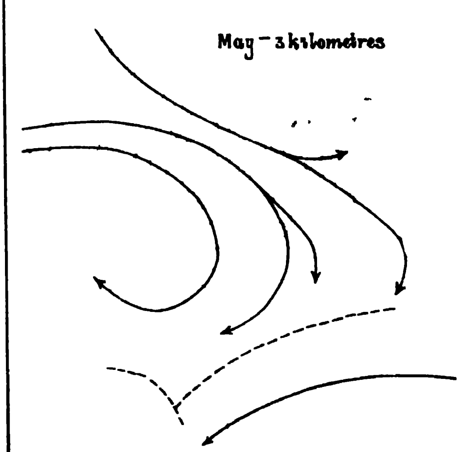

Fig 4c

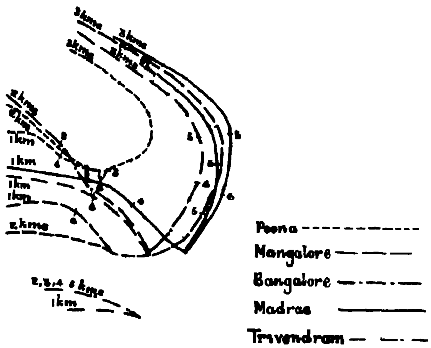

Fig 5 a

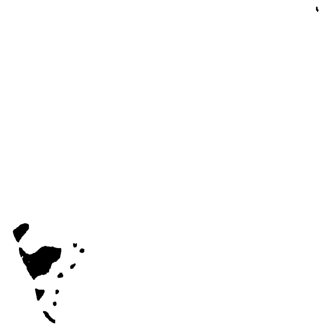

Fig 5 b

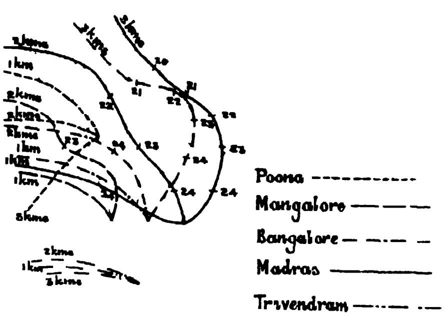

Fig 6 a

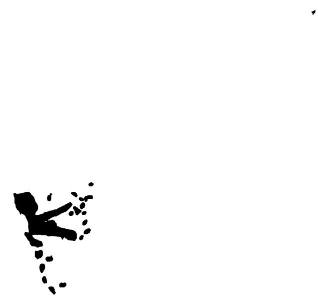

Fig 6 b

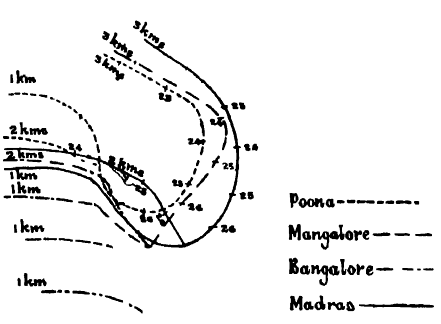

Fig 7 a

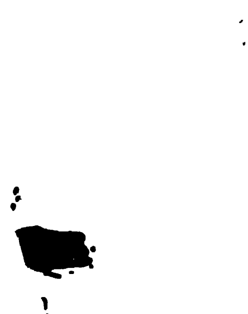

Fig 7 b

Offset G P Z O Poona 1932

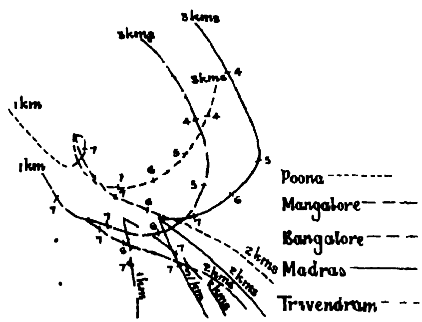

Fig 8 a

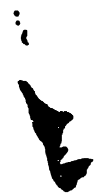

Fig. 8 b

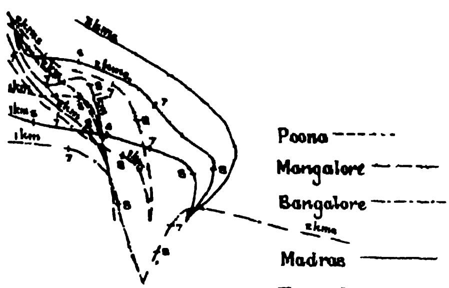

Fig 9 a

Fig 9 b

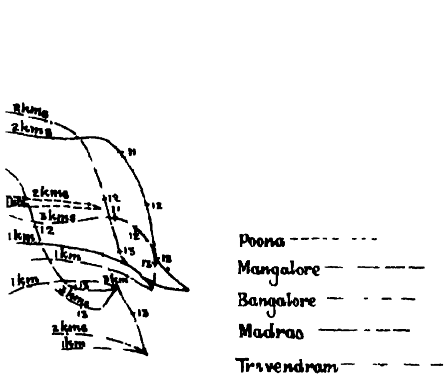

Fig 10 a

Fig 10 b

G P I O POONA 1932

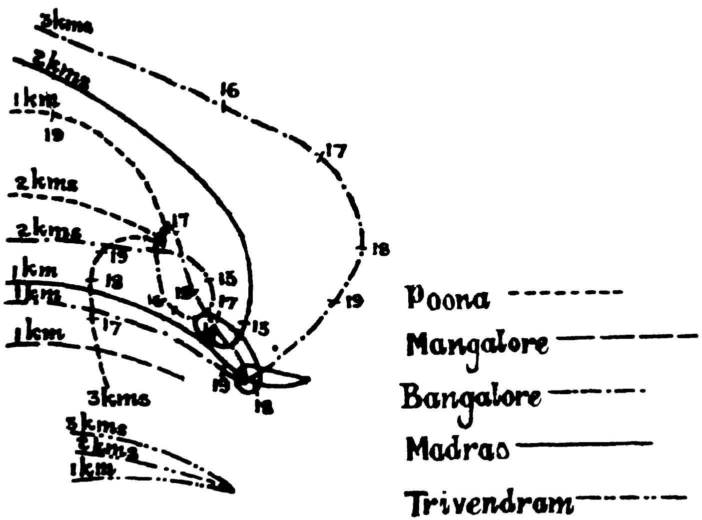

Fig. 11 a

Fig. 11 b

G P Z D 1932

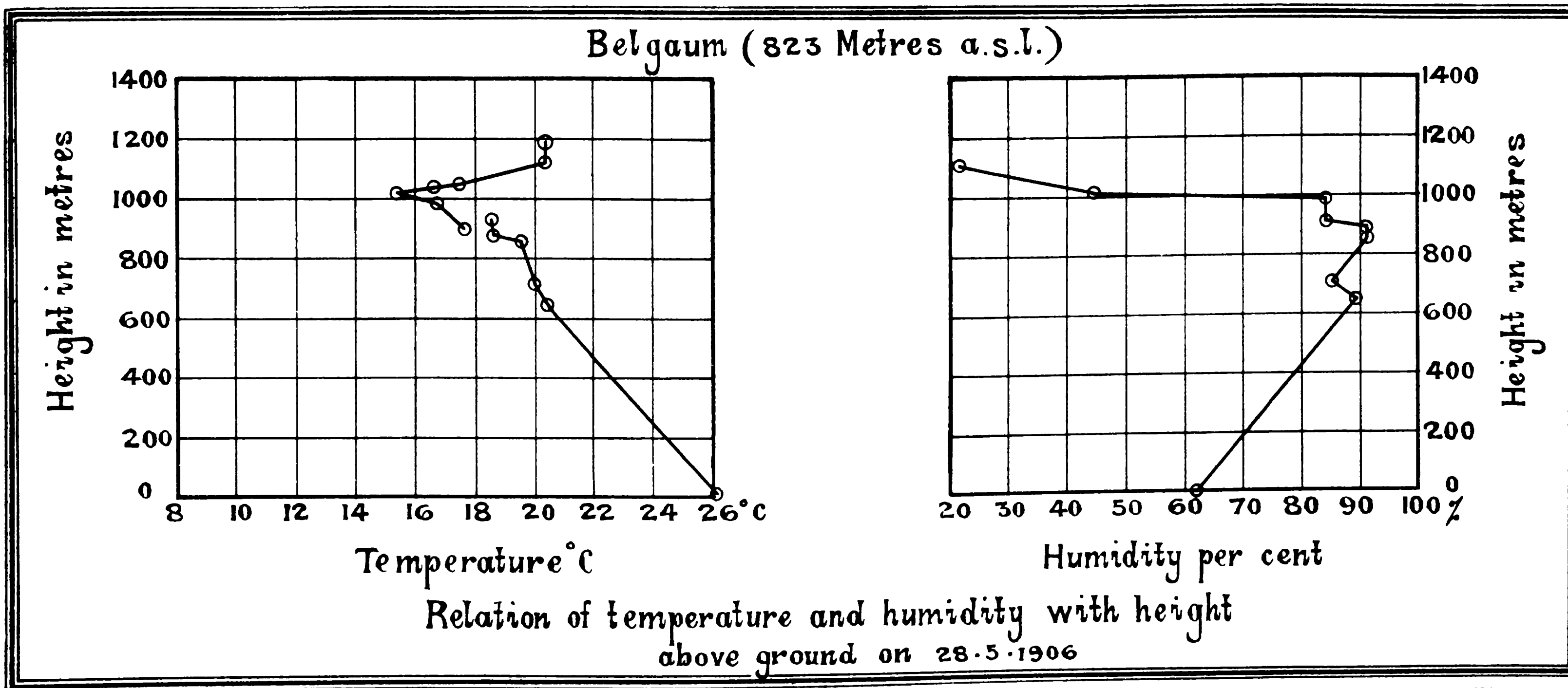
Belgaum (823 Metres a.s.l.)
Height in metres
1400
1200
1000
800
600
400
200
0
8
10
12
14
16
18
20
22
24
26°C
Temperature °C
20
30
40
50
60
70
80
90
100%
Humidity per cent
Relation of temperature and humidity with height
above ground on 28·5·1906
G P Z O POONA, 1932

Fig. 12

INDIA

METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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(*Received on 10th September 1931.*)

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ON THE EXTREME DRYNESS OBSERVED AT KODAIKANAL DURING THE WINTER MONTHS.

BY

S. L MALURKAR.

(*Received on 10th September 1931.*)

Summary—It is known that during the winter months the relative humidity at Kodaikanal often reaches as low values as 4 per cent On examination it was seen that the other hill-stations, at elevations of 2 kms. or more, experienced great dryness The period of great dryness at all the places is generally the same A study of the meteorological conditions of such very dry days is undertaken in this paper

It is shown that the incursion of the cold dry air of North India, which reaches the hill-stations of South India due to the permanent anti-cyclone over Deccan and South India, is not sufficient to account for the extreme dryness The dryness is probably associated with the movement of a dry inversion layer which marks one of the limits of subsidence in the anti-cyclonic region

Introduction.—In the Annual Report of Madras and Kodaikanal Observatories for the year 1899-1900, C Michie Smith writes —" A very striking feature of the climate is the extreme dryness of the air on a number of days during the period December to March Thus, assuming the usual formula to be correct under these extreme conditions, which is unlikely, the relative humidity at 8 a m was only 4 per cent on January 15th and 16th and it was from 5 to 8 per cent on fourteen other mornings The extremely large range of humidity experienced here is very trying to woodwork of all kinds All cameras and darkslides, even if they have been in the tropics for years, require to be carefully examined for cracks at frequent intervals." The year chosen by Michie Smith was extraordinarily dry, judging from the figures above. The fact of the occurrence of very dry days every year is unquestionable In this paper an attempt is made to study in detail the meteorological conditions of such very dry days

Description of the stations.—Kodaikanal is one of the hill-stations of South India (lat 10° 13′ 50″ N, long 77° 28′ E, and elevation 2313 metres) on the upper Palnis, which are an offshoot of the Western Ghats and which are connected with the main body of the Travancore hills to the West The exposure is good at the meteorological station, which is on the summit of the hill *

The other hill-station in South India at a height of 2 kms above sea level which takes meteorological observations at present is Coonoor, at a distance of 168 kms. from Kodaikanal Its geographical position is lat 11° 21′ N, long. 76° 48′ E. and elevation 2·0 kms Past data are available for two other hill stations in the neighbourhood of Coonoor They are Doddabetta, (lat. 11° 25′ N,, long. 76° 40′ E.; elevation 2603 metres) and Ootacamund, (lat 11° 24′ N, long. 76° 44′ E, elevation 2234 metres). Data that are available for Doddabetta are eye observations at 10 and 16 hrs. local time supplemented by continuous records of dry and wet bulb temperatures, pressure, and wind direction and total run Only eye observations at 8 a. m., (local time), are available for Ootacamund A very good general description of the Nilgiri Hills is given by H. F. Blandford in his book on the " Climates of India," page 119.

* I have to thank Dr. A. L. Narayana of Kodaikanal Observatory for the description of the place.

A very cursory glance at the data of these hill stations shows that generally the days are humid in December and January but exceptionally dry days occur at intervals for spells of two or three days The average humidity in February is less than that in the two previous months and so a more detailed study is necessary to distinguish dry days. A day to day graph of humidities for Kodaikanal and Coonoor for the month of January and for a few days in February of 1931 is given, (*Graph 1.*) It is seen that the humidity curves for the two places agree closely, *i.e.*, follow each other. There are exceptions like the 24th and the 31st of January. A possible explanation will be given below For the previous years a simple examination was made and it was found that as a rule the days of low humidity at all hill stations are almost the same.

An examination of the humidity data of the hill station Mercara, of the plateau stations Bangalore, Mysore and Coimbatore and the sea level stations Trichinopoly and Madura whose elevations are below 1 5 kms. yielded neither days of extremely low humidity, nor any obvious relation to the humidity of Kodaikanal. The station Periyakulam at the base of the Palni Hills, where continuous records of meteorological data were made for some years, does not show any degree of dryness comparable with that of Kodaikanal on dry days It may be deduced therefore that the extreme dryness is not confined to any one particular hill station, like Kodaikanal, but is exhibited almost simultaneously at all hill stations at an elevation of about 2 kms. Also the phenomenon is absent at the above-mentioned lower level stations. So it follows that the low water vapour content is a general property of air at about 2 kms and more, throughout South India, on those days

Statistical Examination.– The data relating to the years 1920-29 were examined to deduce most of the conclusions of this paper But when any particular data were wanting during this ten-year period reference was made to the data of other years.

Table I gives the distribution of humidities in the above period. For a majority of the months only the 10 hrs. and 16 hrs (local time) frequencies are given. In order to bring out the fact that there is no essential difference between the 8 hrs. and 10 hrs. frequencies the corresponding frequencies of 8 hrs. are given for the winter months (from December to February). Graphs are given here, (*Graphs 2 to 5*), showing the humidity distribution .–

(i) for the two months December-January,

(ii) for February,

(iii) for a typical monsoon month, July, and

(iv) for November.

As the distribution curves of humidity were similar for the two months December and January a combined graph is given.

It is seen that the frequency distribution at 16 hrs. is represented in all the months by a unimodal curve The 10 hrs curves for months other than the winter months can also be seen to be unimodal But the December-January curve for 10 hrs. shows double maxima. One of the maxima lies at about 25 per cent. and the other at about the point of saturation. That is to say, a large number of days are very humid, but sometimes low values of humidity are reached. The intermediate humidities do not occur often The frequency curve of 10 hrs. for the month of February is flat or has an extended maximum November shows the transition from the pre-winter to winter conditions, *i e*, from the single maximum to the double maximum type of humidity-distribution.

It follows from the above that there are at least two causes operating which determine the humidity of Kodaikanal in the winter months. One of the causes is responsible for the great dryness, and the other for dampness.

Dot diagrams of departures from normal of the maximum, the minimum and the mean temperatures plotted against humidity show that, on days of low humidity, (*i*) the maximum temperature tends to be higher than usual, (*ii*) the minimum tends to be lower than usual, and (*iii*) the mean temperature tends to be above normal.

Out of 620 days of December and January in the five years 1920-24, it was found that there were 100 days with humidity equal to or less than 30 per cent Out of these 100 days, (*i*) there was no cloud on 56 days, (*ii*) there were high clouds on 34 days, (*iii*) there were medium clouds on 9 days, and (*iv*) the sky was overcast with low clouds on only one day The other five years 1925-29 also showed one dry day with overcast sky. Hence, except for very rare occasions, it may be said that the days of low humidity are associated with practically clear skies

The changes in the value of the dry bulb temperature are not sufficient to account for the large variations of relative humidity at the hill stations. For this purpose the vapour pressure of water may be compared on a dry and a wet day As a specific example, at 8 hrs on 18th January 1931, the value of the vapour pressure was 10·2 mm. of mercury, and ten days later, (28th), the vapour pressure was only 0·5 mm The variation of the dry bulb temperature was only from 55° F. on the 18th to 62° F. on the 28th at 8 hrs

On the other hand, the wet-bulb temperature had fallen from 54° F to 40° F. in the same interval. It was found as a rule that, on days of low humidity, the wet-bulb thermometer showed low values, the departure from the normal values being as great as 15° F This shows that the large variation of the relative humidity is due to the large fall in the wet-bulb thermometer As the wet-bulb temperature is indicative of the potential wet-bulb temperature, which is a conservative property of an air mass, it follows that the samples of air near the surface of the hill stations on dry and wet days have not the same origin * Hence it is necessary to trace the origin of the air on dry and wet days

Origin of the air. In what follows, the word "motion" when used without any qualification means a purely horizontal movement, *i e*, a movement such that corresponding portions of air retain the same elevation above sea level.

Upper air trajectories for days of extreme humidity conditions have been drawn for South Indian Stations Only horizontal movement of air has been considered. One trajectory chart is given for a dry day (*Fig 1*). It was seen that on damp days at the hill stations the air supply at about those places came from the Bay of Bengal, and the direction of the incoming stream was ESE to SE. On days of great dryness the trajectories could be traced up to the head of the Bay of Bengal. The period occupied in traversing the distance between the head of the Bay and South India was three to four days At the head of the Bay the upper air movement (above 1 to 1·5 kms.) is from a westerly direction It follows therefore that the air mass found in South India has been controlled by the anti-cyclone existing over Deccan in the winter months.†

It is possible that the horizontal or advectional movement of the air may explain the large variations of relative humidity at Kodaikanal.

The prevailing direction of the winds in South India during winter is all easterly. Hence it is not necessary to consider any air movement from a westerly direction. The winds from a south-easterly direction bring in wetter days, and it is usually seen that these south-easterly winds have had a long sea travel. The air from a north-easterly direction can generally be considered to be a part of the anti-cyclonic

* *Vide* Memoirs of the Indian Meteorological Department, Volume XXIII, Part I, Wet Bulb Temperatures and Thermodynamics of the air, C W. B. Normand, pp. 1 *et seq.*

† See the Upper Air Charts in Indian Meteorological Department, Scientific Notes, Volume I, No. 5; and Volume III, No. 21 of the same series, "Upper Air Circulation over India, etc.," by H.C. Banerjee and K. R. Ramanathan.

circulation and hence the origin may be traced to North India. The air in North India is generally dry in winter at all the levels and so it may be imagined that this air moving horizontally to reach lower latitudes gets heated up slowly and ushers in dry days at Kodaikanal. If this view should be tenable the other consequences of such an assumption would be —

(1) The advent of dryness at Kodaikanal should bring in colder days than usual as potentially colder air is reaching the place.

(2) The dryness should also be associated with a fall of wet-bulb temperature. Hence the continuous records which are available should show a fall of dry-bulb temperature with the fall of wet-bulb temperature, and the dry-bulb temperature must continue to fall as long as wet-bulb temperature falls

(3) Stronger winds should bring in more supply of dry air and hence the humidity should be lower on days of stronger winds than on relatively calmer days

(4) The vapour pressure at Kodaikanal should not be less than that found at equally great elevations in North India, either from sounding balloon data or day to day observations at some hill-station. In the cases examined no precipitation had taken place along the path of the air.

(5) There should be some relation between the time of occurrence of low humidities in North India hill stations and Kodaikanal.

The results of dot diagrams show that the air temperature actually tends to be greater on very dry days An examination of the continuous records of Richard's dry and wet bulb thermometers has been made It was found that when the humidity was constant, no special characteristics were found in the dry and wet-bulb records But a transition from high to low humidity is accompanied by very special changes. The wet-bulb temperature falls, often abruptly, by nearly 5° F. or more, and the dry-bulb temperature rises soon after by an amount which is variable but is always less than that of the wet-bulb temperature It is possible to see pulses of fall of wet-bulb temperature and rise of dry-bulb temperature and *vice versa* (See *e g*, *Fig. 3*). A detailed study of some transition days is given in Table II. Some of the autographic records of Kodaikanal are given in *Figs. 2-7.*

It may also be noted that the transitions of high to low humidity take place at night or in the evening.

On days of low humidity at Kodaikanal the upper air velocities, as found from the pilot balloon data of South India stations, are smaller than usual at levels 2 km—4 km.

The upper air humidities over Agra cannot be used profitably for this work as the soundings have not been made over a continuous period. Simla is one of the driest North India stations at an elevation of 2 kms. The vapour pressure at Simla often falls to very low values A search to find some time-relation between the periods of occurrence of low humidities at Simla and Kodaikanal gave a negative result. On February 9th, 1931, the vapour pressure at Kodaikanal was less than 0·02 mm of mercury. Simla had not experienced such a dry day in the immediate past.

Taken cumulatively, these reasons show that advectional motion of air cannot alone or even chiefly account for the extreme dryness observed at Kodaikanal.

No sounding balloon data exist for the south of the peninsula ; but some insight can be gained about the changes of temperature from the ground upwards from the continuous records of Periyakulam and Kodaikanal in the past years. The difference of level between the two stations is 6744 ft. (2·06 km). At 8 hrs. in the morning the difference of temperature between the two stations is as much as 24° F. on days

of high humidity and as small as 7° F. on days of low humidity. Hour to hour readings for the two stations for the days 12th-14th January 1909 are given in Table III. The difference of temperature drops from 13·5° F. at 8 hrs. on 12th to 6·3° F and 6·4° F. at 7 and 8 hrs. of 13th respectively, and rises again by next morning to 20·7° F. It follows therefore that below the level of Kodaikanal a layer of inversion exists on very dry days The exact height is not available at present as no observations have been taken Some information can however be derived from the few sounding balloon data at Poona for the past two or three winters. It is possible to find a layer of inversion from the Poona sounding balloon data which is common with the inversion layer as derived from the pilot balloon data of the South Indian stations. A dot diagram of such an inversion layer at Poona and the corresponding humidity at Kodaikanal is given in *Graph 6*. It can be seen that the inversion over Poona, and probably therefore over the Deccan, is at lower levels as the day is drier at Kodaikanal.

Discussion.—From what has been said above it follows that samples of air of different origin are to be found at Kodaikanal on very dry and very wet days, and that advectional movement of air alone cannot account for the extreme dryness experienced The only possible origin of dry air is from above That is, the air has actually descended from higher levels In a theoretical case the rate of descent was calculated by Napier Shaw to be very small (86m day) in the case of a stationary anti-cyclone, and to be slightly larger in the case of a developing one In a permanent anti-cyclone the descent of air is so slow that the descending air will acquire approximately the normal temperatures at every stage In a developing anti-cyclone, the descending air will probably not have so much time to transfer its heat to its surroundings and it is likely that the descending air will be warmer than its neighbourhood It may be expected therefore that in a developing anti-cyclone the advent of dry air may bring in warmer days

A dry inversion layer marks the lower limit of subsidence. It is seen from *Graph 6* that this inversion layer descends to lower levels sometimes and that great dryness is experienced at Kodaikanal simultaneously. It may be presumed that the anti-cyclonic subsidence is occurring every day in winter , but the inversion layer is generally far above the elevations of the hill-stations of South India When this inversion layer lies below the level of some of the hill stations, these stations experience great dryness. Those hill-stations below the inversion layer do not exhibit any very low humidity. We cannot at present ascertain the factors that determine the movement of the inversion layer. Sverdrup's observations showed that strong advectional currents are not favourable for the formation of inversion layers * From the remarks given earlier, on dry days the upper air velocities (at elevations 2 to 4 kms. above sea-level) are smaller than usual , and so the calmer state of air is much less unfavourable for the formation of inversion layers at lower levels But on days of strong winds the inversion layer or the lower limit of subsidence is lifted up. It is also possible that the calmer state of the upper air on dry days is less favourable for the quick replacement of fresh air horizontally and for a rise of humidity.

In addition to the dry inversion layer, it is possible that other inversion layers exist at lower levels. For want of data no investigation into their causes has been made. The lower inversion is probably due to the radiation losses from layers of air very near the ground level. During clear nights and early mornings in winter turbulence tends to disappear and favours the formation of the inversion layer. It is also possible that subsidence occurring at higher levels may help the sharpening of the layer of discontinuity.

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* H. U. Sverdrup. Monthly Weather Review, Washington, 1925, pp. 471—475 " On the North Polar Cover of Cold Air."

When this investigation was complete, my attention was drawn to a paper on similar lines by Hoffmeister,* for stations in Central Europe, which finished with similar conclusions.

I have to express my great obligation to Dr. C. W. B. Normand for the suggestion of the problem and for helpful advice I thank the Director of Kodaikanal Observatory for kindly placing at my disposal all the relevant material.

TABLE I.

Months	Number of days when humidity lay in the range									
	0 —9	10 —19	20 —29	30 —39	40 —49	50 —59	60 —69	70 —79	80 —89	90 —100
January—										
8 hrs	2	33	38	18	24	18	22	26	37	92
10 hrs.	2	24	44	30	32	25	43	26	20	64
16 hrs	1	2	6	18	32	26	34	68	56	67
February—										
8 hrs.	4	21	31	32	30	39	42	24	30	29
10 hrs	6	25	36	47	52	43	34	13	15	42
16 hrs	0	4	18	36	40	29	48	50	36	22
March—										
10 hrs	6	32	61	59	59	30	32	15	12	4
16 hrs	0	1	21	34	51	47	56	46	30	24
April—										
10 hrs	0	1	27	53	52	51	52	35	24	5
16 hrs	0	0	1	8	27	38	52	70	61	43
May—										
10 hrs	0	3	9	19	54	82	67	50	19	7
16 hrs	0	0	1	5	5	21	40	89	107	42
June—										
10 hrs.	0	0	0	5	7	23	69	116	58	22
16 hrs.	0	0	0	0	1	7	28	69	101	94
July—										
10 hrs	0	0	0	1	2	18	35	98	102	54
16 hrs	0	0	0	0	1	8	16	55	108	122
August—										
10 hrs	0	0	0	0	3	17	55	111	104	20
16 hrs.	0	0	0	0	2	3	12	45	121	127
September—										
10 hrs	0	0	0	2	10	18	40	118	96	16
16 hrs	0	0	0	0	2	3	15	42	123	115
October—										
10 hrs.	0	0	2	10	18	18	33	68	93	68
16 hrs.	0	0	0	0	4	5	17	38	86	160
November—										
10 hrs.	0	9	8	9	14	16	28	43	56	117
16 hrs.	0	1	3	2	6	11	9	30	74	164
December—										
8 hrs.	1	32	36	17	24	20	25	20	29	106
10 hrs.	0	36	32	26	23	29	32	25	34	73
16 hrs.	1	0	9	8	18	24	39	48	56	107

* J. Hoffmeister, Ein Beitrag zur Untersuchung niedriger Luftfeuchtigkeitswerte auf der Schneekoppe und auf dem Brocken, Bericht über die Tätigkeit des Preuss. Met. Inst. im jahre 1930, Berlin, 1931.

Table II.

Detailed study of the thermograms at Kodaikanal for the transition days 16th-17th December 1929, and 30th-31st December 1929. (Times are reckoned from midnight.)

Date.	Time hrs	Time Min	Dry Bulb ° F	Wet Bulb ° F	Humidity relative (%)	Humidity absolute (in mms.)
16th December 1929	8	0	52·4		33	3·35
	10	0	56·1	43·4	35	3·78
	16	0	59·3	50·0	33	6·68
	18	0	55·3	50·8	74	8·31
	20	0	48·3	41·7	59	5·06
	22	0	48·7	42·0	64	5·31
17th December 1929*	0	0	48·4	44·4	74	6·36
	0	15	48·2	44·1	74	6·36
	0	30	48·1	43·9	74	6·17
	0	45	48·0	44·0	74	6·25
	1	0	46·9	43·2	76	6·05
	1	15	46·1	44·0	63	5·08
	1	30	45·4	37·0	43	3·35
	1	45	47·8	36·0	27	2·29
	2	0	49·4	36·2	21	1·88
	2	15	49·4	36·6	22	2·18
	2	30	48·4	37·1	31	2·56
	2	45	47·4	38·1	44	3·50
	3	0	48·7	37·1	30	2·56
	3	15	48·8	37·0	29	2·44
	3	30	49·5	37·4	28	2·44
	3	45	49·2	39·1	39	3·40
	4	0	49·1	40·0	44	3·91
	4	30	49·9	38·3	31	2·79
	5	0	50·1	38·5	31	3·02
	5	30	50·1	37·0	24	2·19
	6	0	49·4	37·0	26	2·51
	8	0	52·9	42·7	43	4·38
30th December 1929	8	0	60·0		39	5·18
	20	0	47·0	42·6	70	5·73
	22	0	43·6	39·4	69	5·02
	0	0	43·5	38·6	65	4·57
	0	15	43·1	38·6	65	4·59
	1	0	43·3	34·6	40	2·72
	1	15	46·1	34·6	25	1·96
	1	30	46·6	34·4	22	1·85
	1	45	47·1	34·5	22	1·90
	2	0	46·1	34·6	25	1·96
	2	15	45·1	34·1	28	2·08
	2	30	46·1	33·6	20	1·63
	2	15	48·2	33·8	12	0·99
31st December 1929	3	0	48·1	34·0	15	1·27
	3	15	48·1	33·7	13	1·12
	3	15	45·6	34·1	21	1·70
	4	0	45·2	33·6	24	1·88
	4	15	46·1	33·1	18	1·37
	4	30	47·1	33·6	16	1·35
	4	45	47·9	33·6	12	1·09
	5	0	48·2	34·1	15	1·30
	6	0	48·1	34·6	19	1·63
	8	0	54·9	39·3	18	1·98

* Note the pulses mentioned before with humidity maxima at 0 hr. 0 min., 2 hr. 45 min., 4 hr., 5 hr., of 17th December 1929. (See also Fig. 3.)

TABLE III.

Date and Time	Kodaikanal Dry Bulb	Kodaikanal Wet Bulb	Humidity Rel	Humidity Abs	Periyakulam Dry Bulb	Difference of Dry Bulb
12th January 1909 —						
8 hrs	53 2	36 9	13	1 32	66 7	13 5
9	55 8	39·9	18	2·08		
10	58 4	40 6	14	1 72	74 9	16 5
11	60 2	41 8	11	1 91	77 3	17 1
12	61 4	43 5	18	2 44	79·0	17 6
13	62 1	45 0	22	3 10	80 8	18 7
14	62 0	46 6	29	4·08	82·6	20 6
15	61 1	45 3	25	3 45	82·1	21·0
16	60 2	41 5	13	1 70	81·7	21 5
17	56 8	39 6	14	1 65	80 4	23 6
18	53 8	37 2	12	1 27	76 6	22 8
19	52 8	36 0	9	0 99	73·4	20 6
20	52 3	35 6	9	0 89	71 8	19 5
21	52 2	35 1	7	0 71	70 1	17 9
22	52 1	36 2	12	1 20	68 7	16 6
23	49 7	35 0	15	1 30	66 9	17 2
13th January 1909—						
0 hrs	49 1	35 0	17	1 50	66 6	17 5
1	50 3	34 9	12	1 12	65 1	14 8
2	48 9	34 4	14	1 17	63·4	14 5
3	50 4	33 8	7	0 64	62·5	12·1
4	50 2	32 7	3	0·20	61 6	11·4
5	49 5	32 6	4	0 33	60 6	11 1
6	49 4	32 3	4	0 35	59·7	10 3
7	53 4	35 0	3	0 33	59 7	6 3
8	59 2	39 6	8	1·17	65 6	6 4
9	60 1	40 9	12	1 52	71 2	11 1
10	63 8	43 0	10	1 52	74 0	10 2
11	66 1	47 8	22	3 60	76·4	10 3
12	65 3	47 8	24	3 86	78 6	13·3
13	64 6	47 8	26	4 06	80 6	16·0
14	64 0	48 8	31	4 77	82·1	18 1
15	64 4	47 3	24	3 71	82 8	18 4
16	60 9	45 8	29	3 91	82 6	21 7
17	57 6	43 7	30	3 58	80 6	23 0
18	53 8	40 8	29	3 10	77 6	23 8
19	51 5	40 4	34	3 25	76 5	25 0
20	47 2	41 9	61	5 30	74·8	27 6
21	48 1	39 0	41	3 53	73 7	25 3
22	46 5	39 5	57	4·57	71 7	26 2
23	46·4	37 6	42	3 45	72 6	26 2
14th January 1909—						
0 hrs	45 4	38 8	[illegible]	4 18	69 7	24 3
1	48·3	43 1	[illegible]	5·71	69 5	21·2
2	49·5	44 5	68	6·10	68 6	19·1
3	49 6	44 8	71	6 25	68·6	20·0
4	48 9	44 2	71	6 12	68·6	19·7
5	49 5	44 8	71	6 40	68 6	19·1
6	49 5	44 7	71	6·40	67 8	18·3
7	49 6	44 8	70	6·52	67·6	17·0
8	50 1	45 3	71	6·45	70·8	20·7

The temperatures are in Fahrenheit degrees and the absolute humidity in millimetres of mercury at latitude 45 and 32° F.

M35DGofOb.—25-4-32—360—GIPS

Trajectories of Upper Air.
17th December 1930.

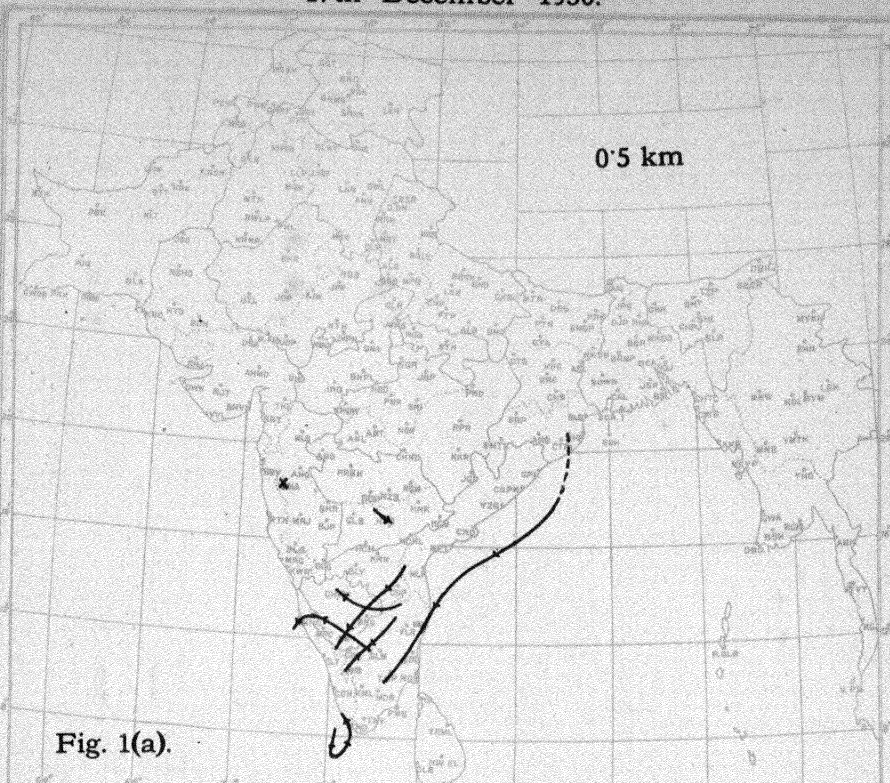


Fig. 1(a).

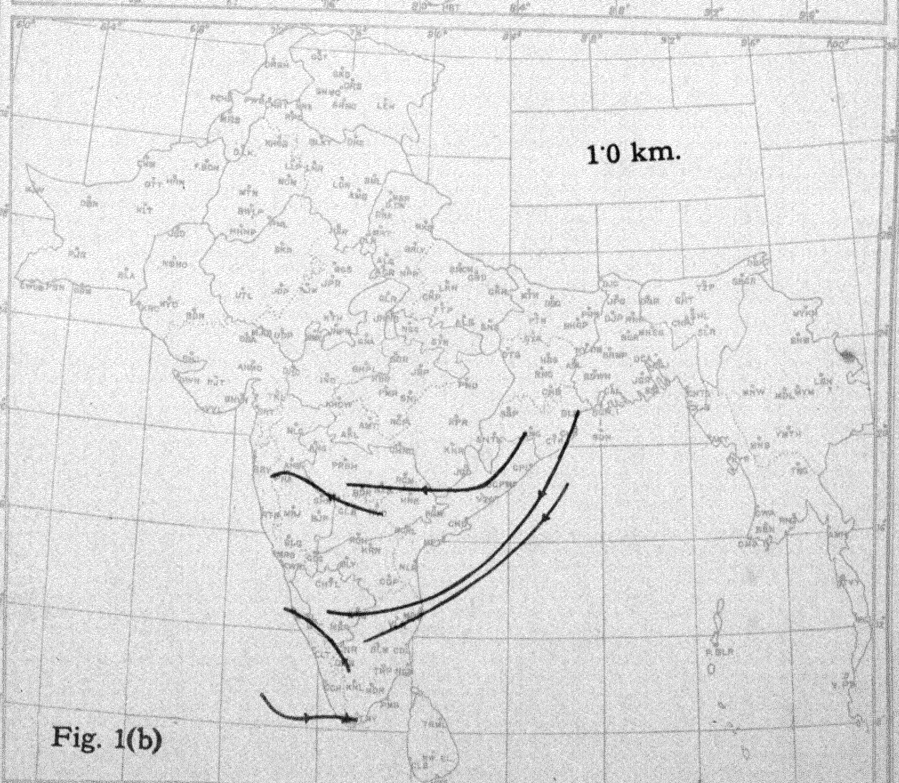


Fig. 1(b)

Trajectories of Upper Air.
17th December 1930.

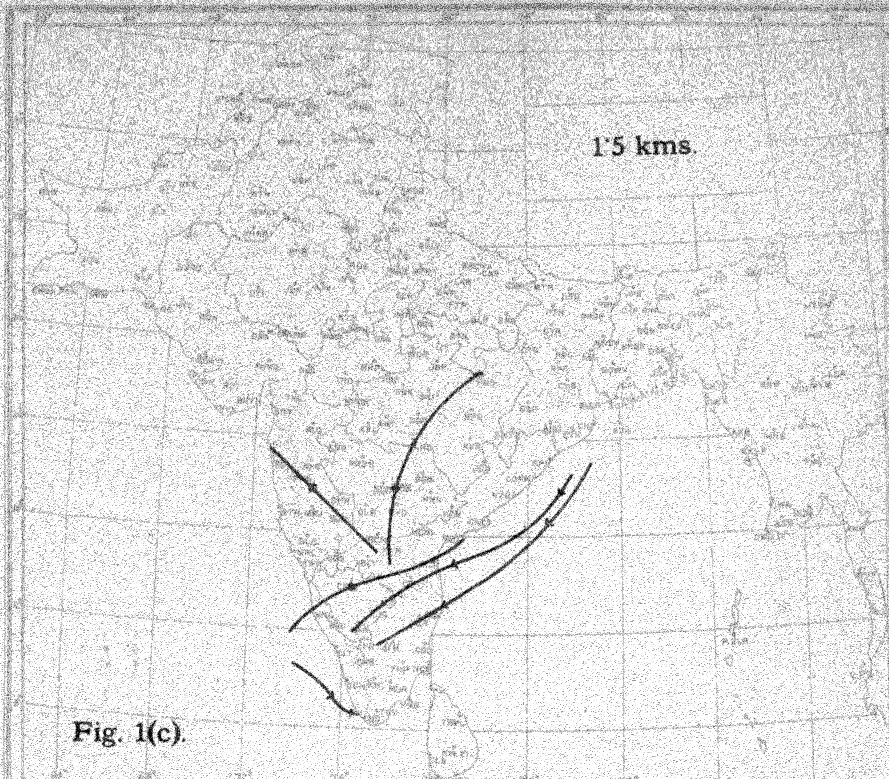


Fig. 1(c).

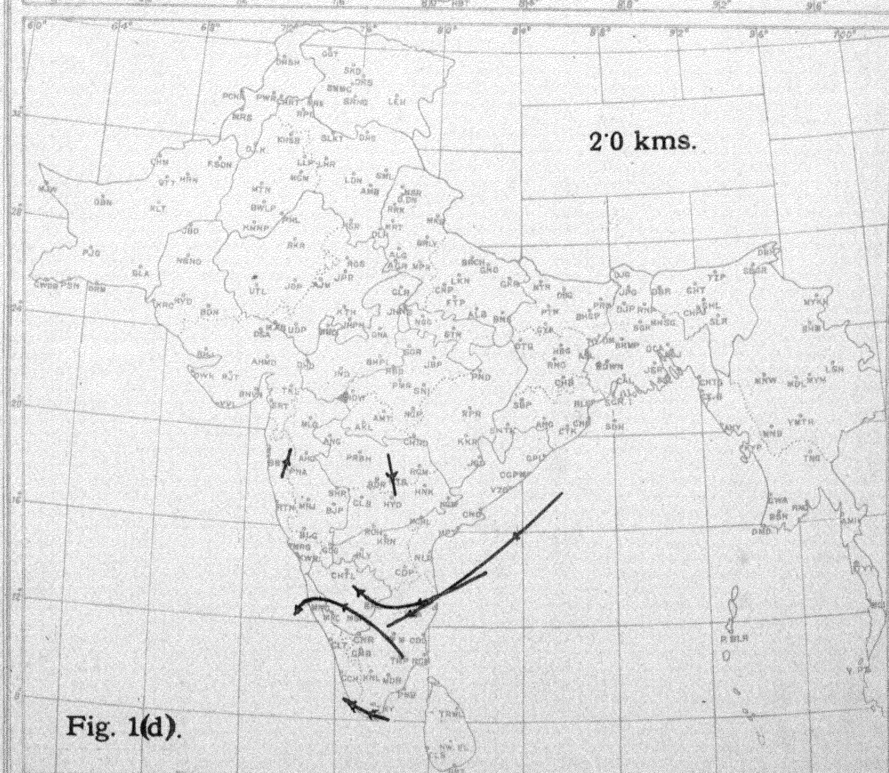


Fig. 1(d).

Trajectories of Upper Air.

17th December 1930.

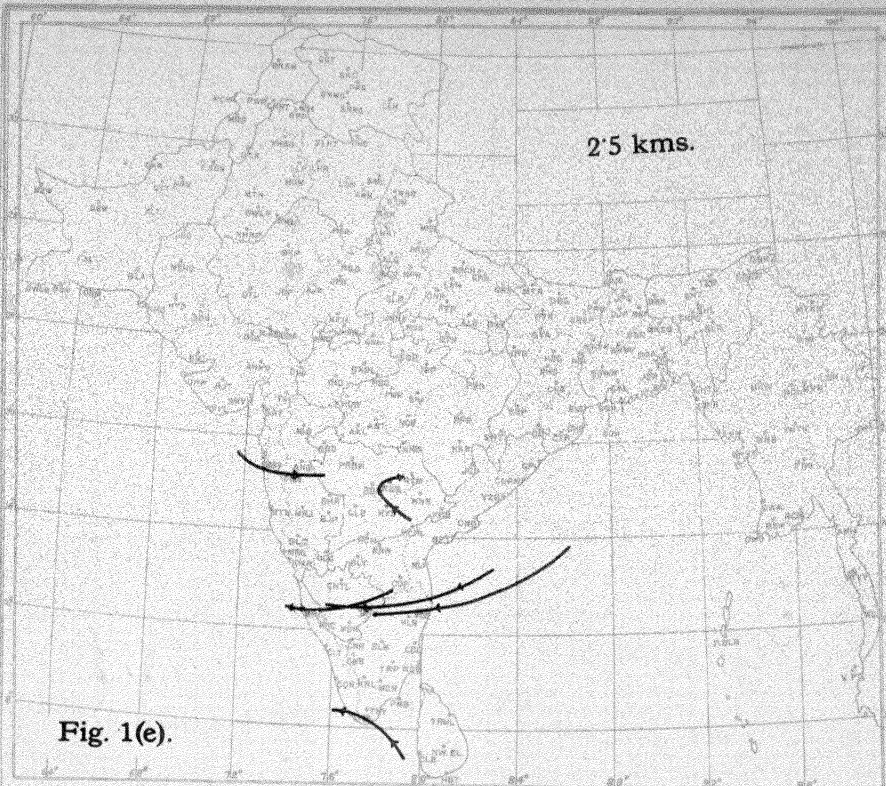


Fig. 1(e).

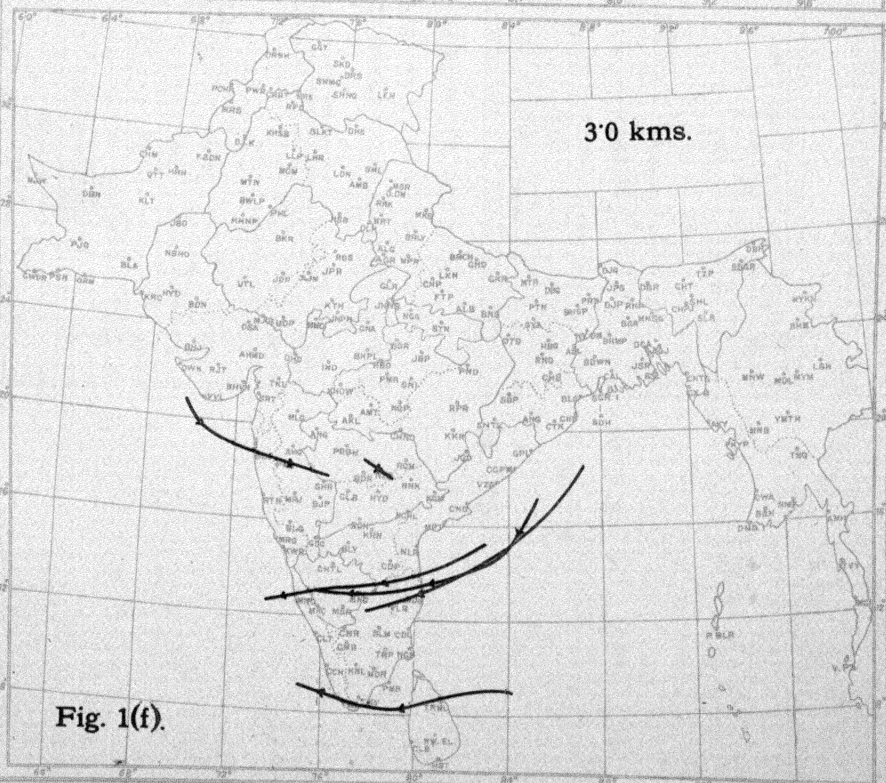


Fig. 1(f).

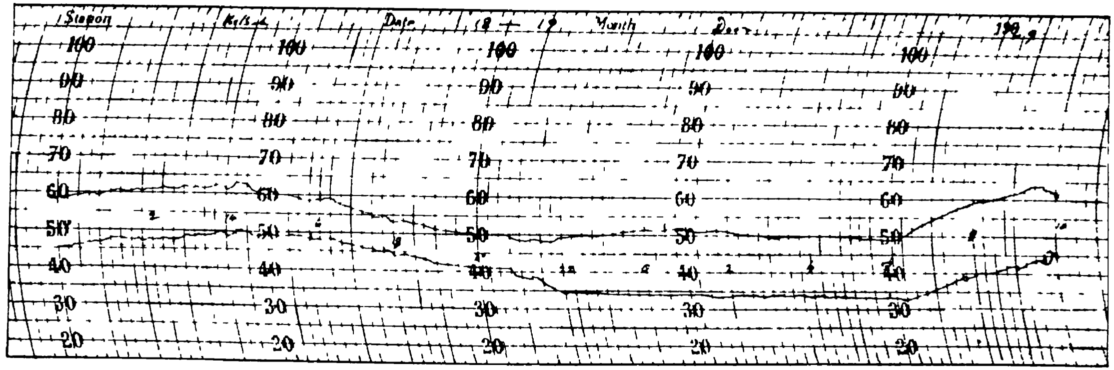


Fig. 2. Autographic chart of D B. and W.B. thermometers Kodaikanal. From 10 hrs. of 18-12-1929 to 10 hrs of 19th.

Note the fall of W.B at 21 hrs. 15 mins.

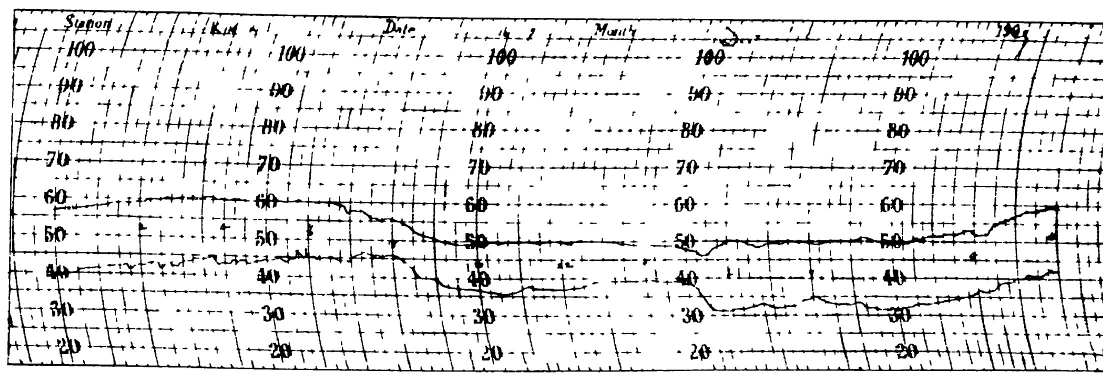


Fig. 3. A detailed description of this chart 16th -17th-12-29 is given in Table II

G P Z O POONA, 1932

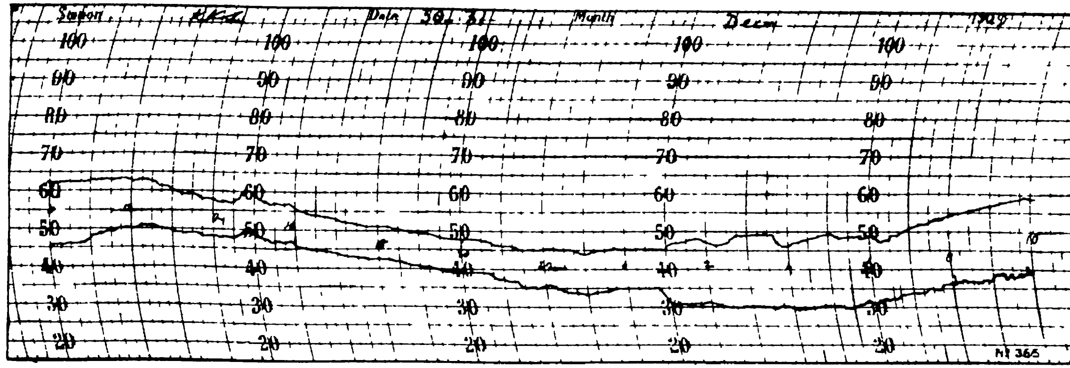


Fig. 4. Chart for 30th-31st December 1929 A transition day. See the sharp fall of W.B. at 0 hr. 45 mins.

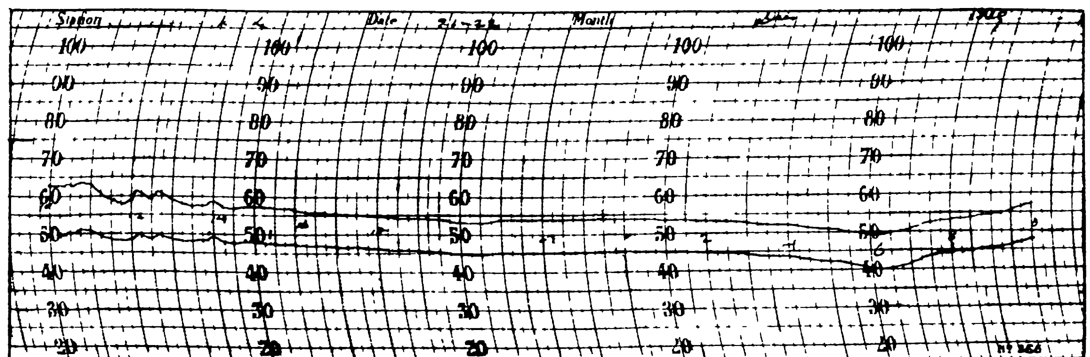


Fig. 5. Chart for 21st-22nd December 1929. A wet day. Both D.B. and W.B. traces run uniformly.

G P X O POONA 1932

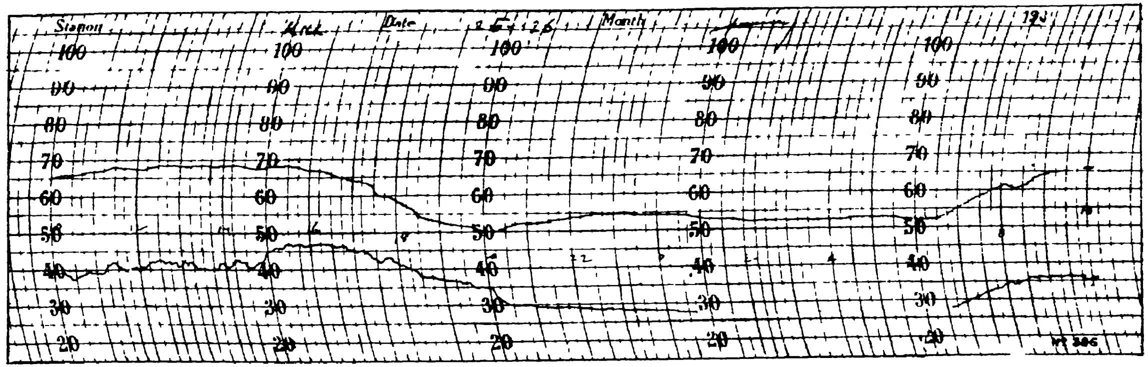


Fig. 6. Chart for 25th-26th of January 1931 from 10 hrs. to 10 hrs (local time).
Note the change at 20 hrs.

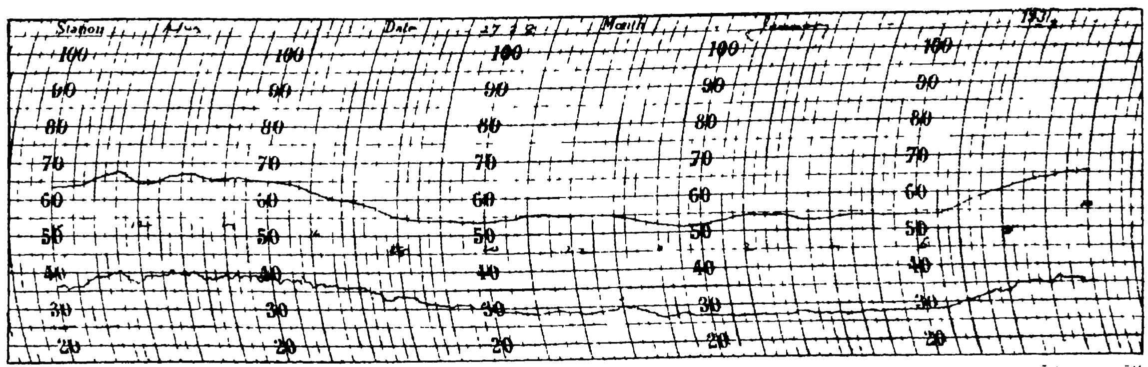
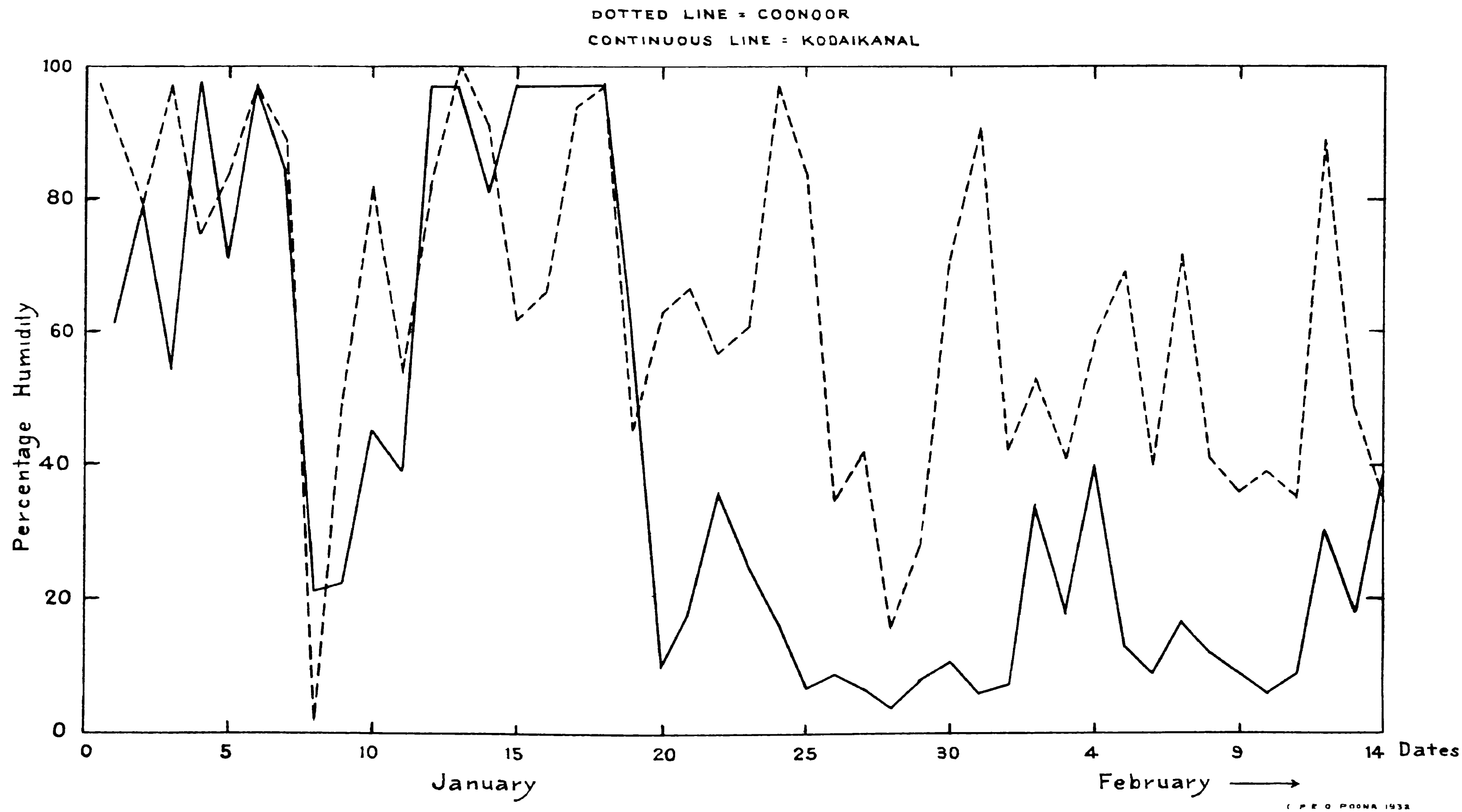


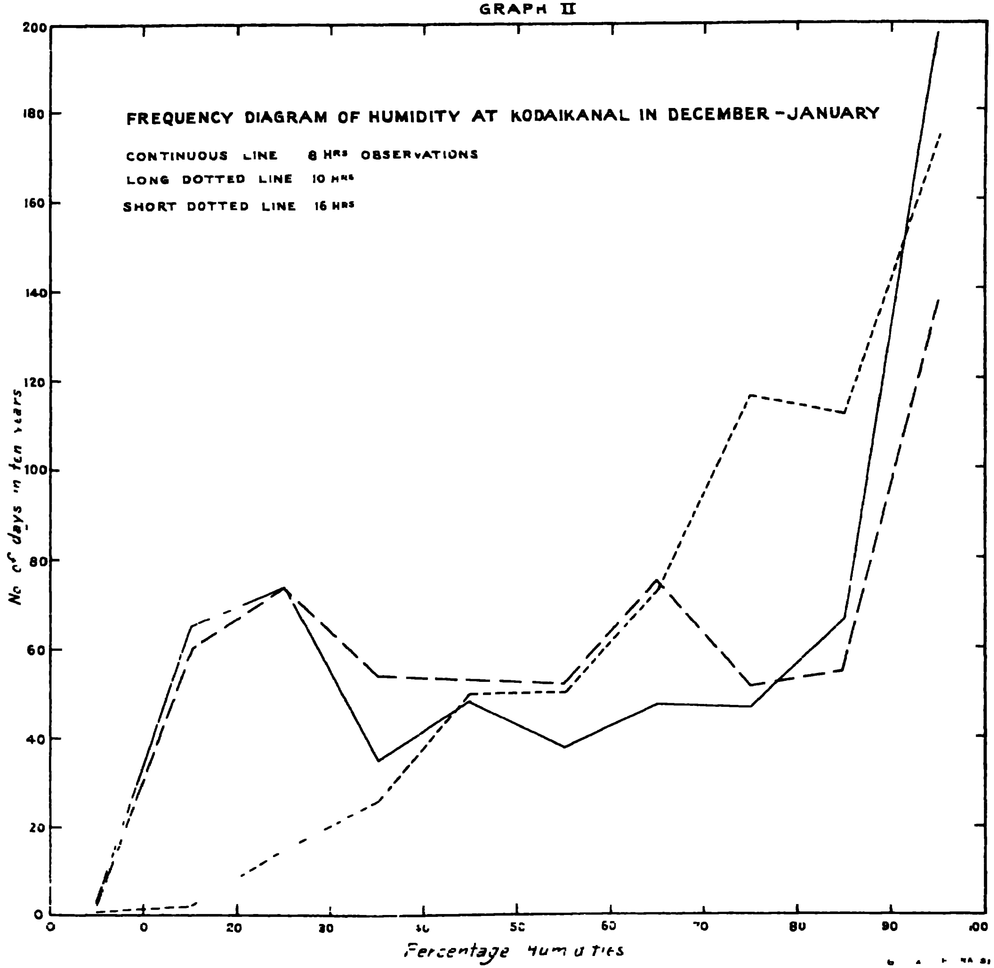
Fig. 7. Chart for 27th-28th January 1931. A dry day.
Note the pulses after 20 hrs.

GRAPH I

COMPARISON OF DAY TO DAY HUMIDITIES AT KODAIKANAL & COONOOR



GRAPH II


FREQUENCY DIAGRAM OF HUMIDITY AT KODAIKANAL IN DECEMBER - JANUARY
CONTINUOUS LINE 8 HRS OBSERVATIONS
LONG DOTTED LINE 10 HRS
SHORT DOTTED LINE 16 HRS
No cf days in ten years
Fercentage Hum d ties
0
20
40
60
80
100
120
140
160
180
200
0
10
20
30
40
50
60
70
80
90
100

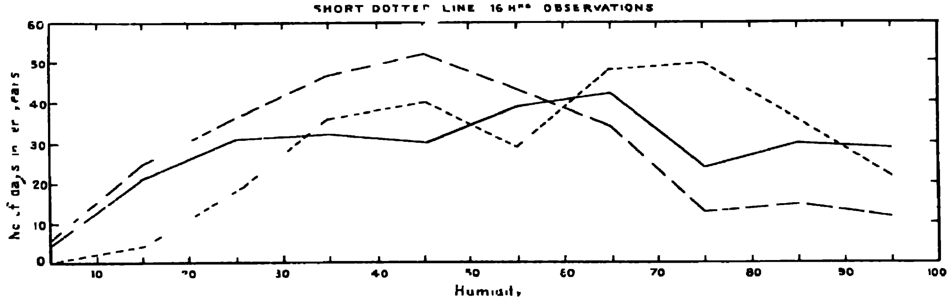
GRAPH III

FREQUENCY DIAGRAM OF HUMIDITY AT KODAIKANAL IN FEBRUARY

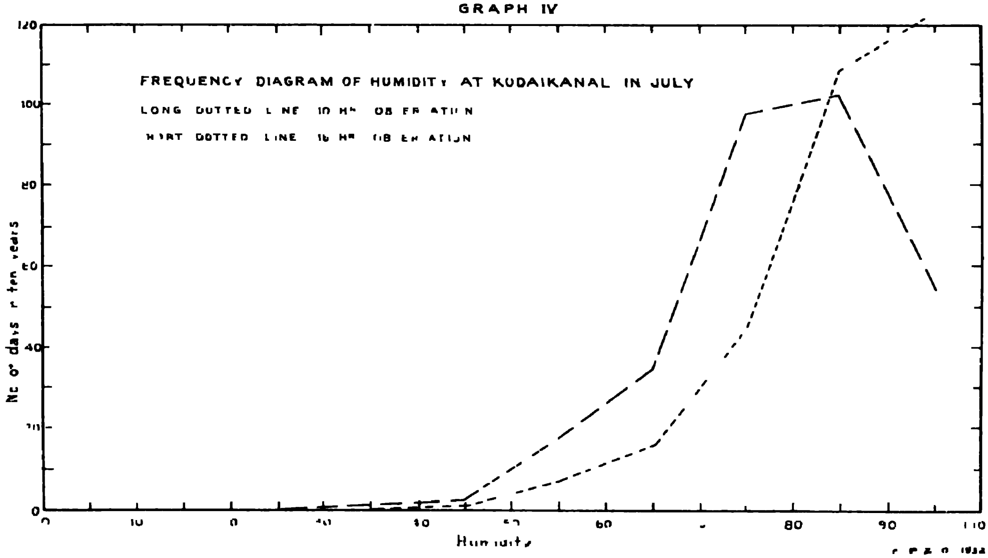
CONTINUOUS LINE 8 HRS OBSERVATIONS

LONG DOTTED LINE 10 HRS OBSERVATIONS

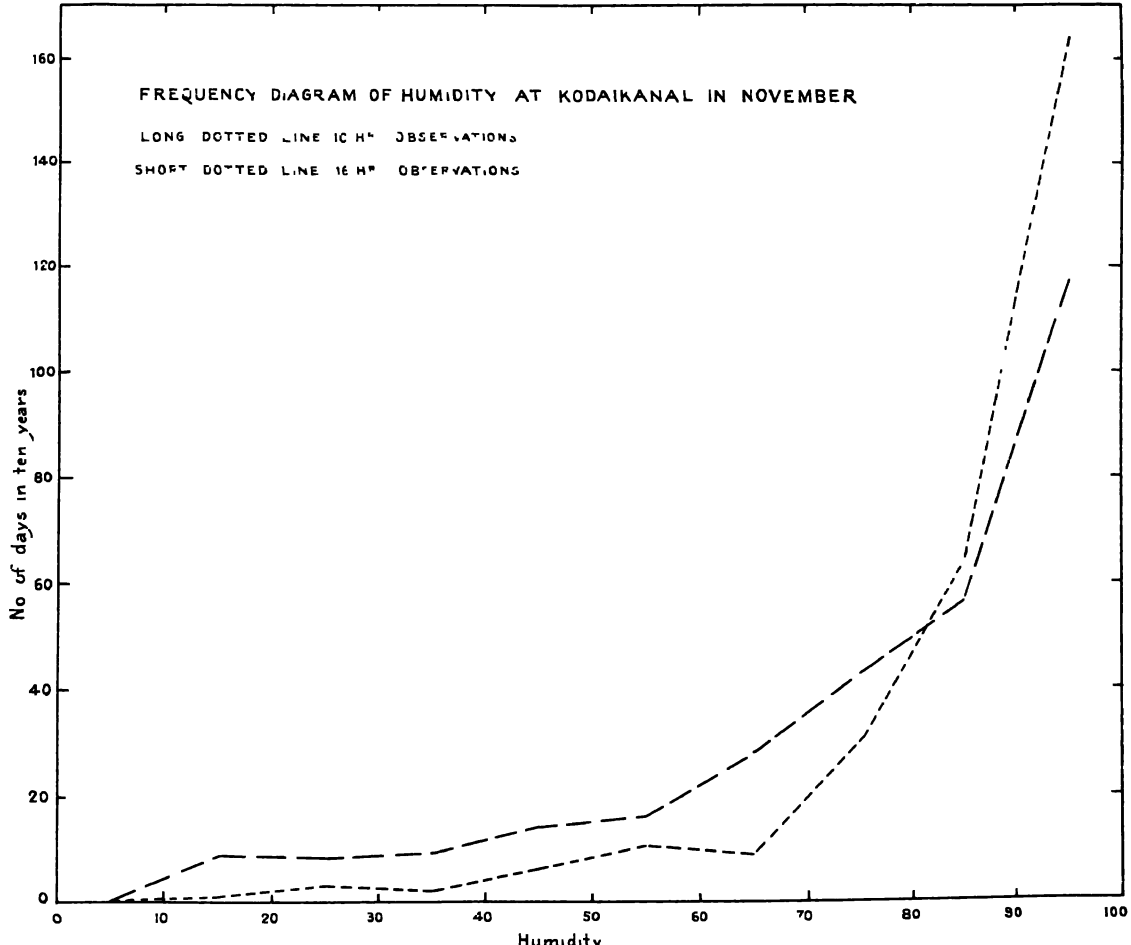
SHORT DOTTED LINE 16 HRS OBSERVATIONS



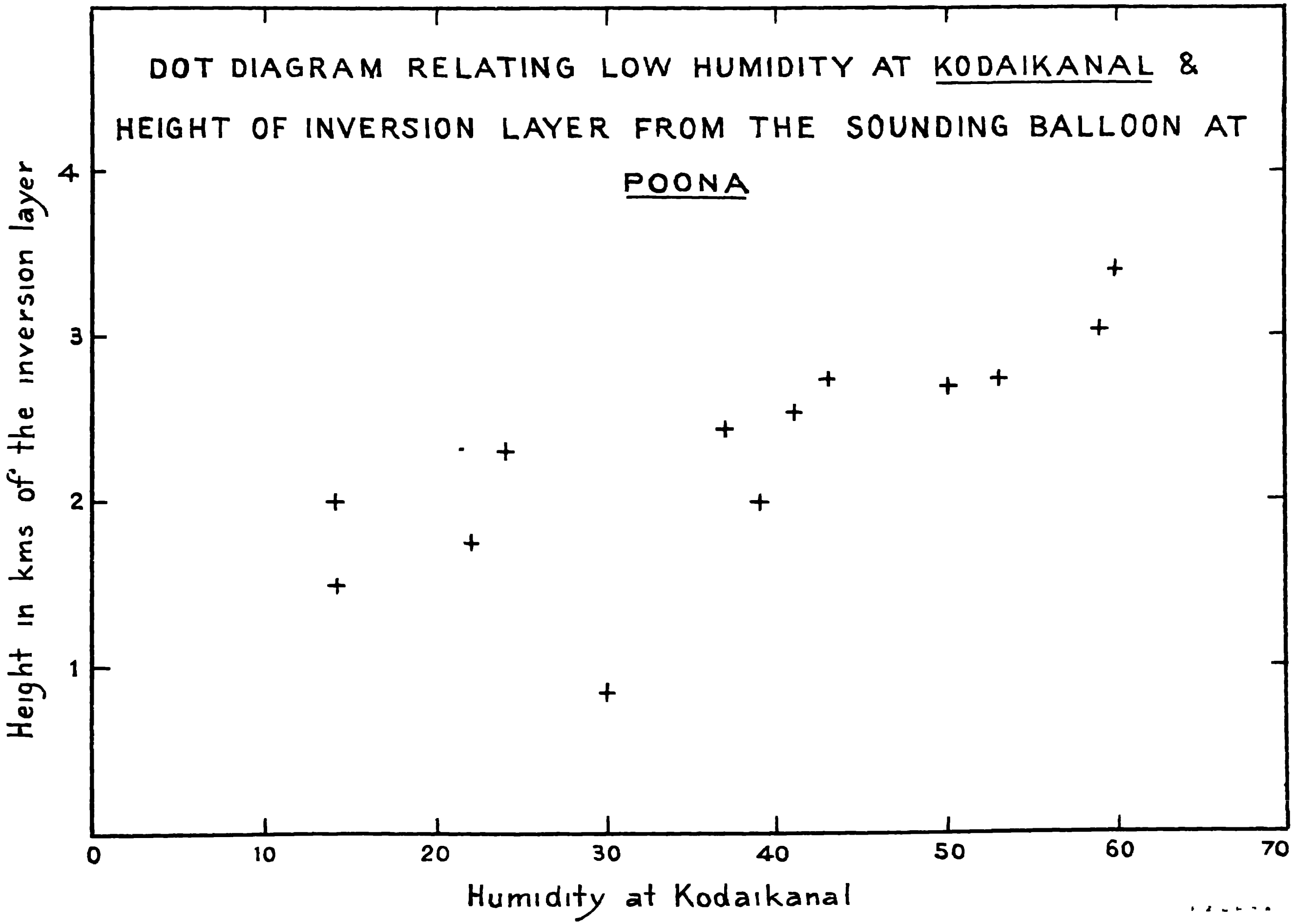
GRAPH IV



GRAPH V


FREQUENCY DIAGRAM OF HUMIDITY AT KODAIKANAL IN NOVEMBER
LONG DOTTED LINE 10 H OBSERVATIONS
SHORT DOTTED LINE 16 H OBSERVATIONS
No of days in ten years
160
140
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
Humidity

GRAPH VI


DOT DIAGRAM RELATING LOW HUMIDITY AT KODAIKANAL &
HEIGHT OF INVERSION LAYER FROM THE SOUNDING BALLOON AT
POONA
Height in kms of the inversion layer
4
3
2
1
0
10
20
30
40
50
60
70
Humidity at Kodaikanal

INDIA
METEOROLOGICAL DEPARTMENT

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A DISCUSSION OF MONTHLY MEAN VALUES OF UPPER AIR TEMPERATURES AND HUMIDITIES OBTAINED FROM AEROPLANE ASCENTS AT PESHAWAR AND QUETTA

By

A. NARAYANAN, M.A.

(*Received on 11th March 1931.*)

Summary.—The paper contains an analysis of the daily observations of temperature and humidity made from R. A F. aeroplanes at Peshawar during the years 1927 to 1929, and at Quetta from June 1927 to May 1930. The method of working out the data is briefly described and tables of mean monthly values of temperature, lapse-rate and relative humidity for different heights are given. The seasonal variations of temperature and humidities over the two stations have been briefly discussed Tables of mean monthly differences in temperature between Agra (from sounding balloon ascents) and Peshawar, and Agra and Quetta have also been given

Introduction.—Observations of dry and wet bulb mercury thermometers have been taken almost daily at different heights over Peshawar and its neighbourhood from R. A F. aeroplanes since December 1926 Similar observations were started at Quetta in June 1927, but till the end of December 1928 daily observations were not made, the number being only about 7 or 8 per month. From January 1929, however, observations are being made on almost all days there also. The setting of the instruments, the instruction of observers, and the collection of observations were done by the R. A F Meteorological Officers, Flt Lt Vervard at Peshawar and Flt Lt Batty at Quetta The thermometers used were of the Mark III pattern (Makers, S. & A Calderara) made according to the specifications of the London Meteorological Office. They had a range from 0-130° F Two thermometers were mounted on a wooden board—one dry bulb and the other wet bulb A copper vessel was provided for holding water for the wet bulb A frame holding two convex lenses sliding on two vertical rods fixed to the board was placed in front of the thermometers at such a distance that readings could be taken from a distance of 4 to 5 feet. The sliding frame was operated by a piece of cord The psychrometer was lashed to one of the struts of the aeroplane The data up to the end of June 1928 were worked out and tabulated in the Upper Air Observatory, Agra Since that date the data are being worked out in the Upper Air Section at Poona In this paper an analysis is made of the Peshawar data from January 1927 to December 1929 and of the Quetta data from June 1927 to May 1930.

Peshawar Data.—The daily ascents were not all made from Peshawar, but were made from one of the three stations Risalpur, Peshawar and Kohat in a more or less regular cyclical order, for two weeks from Risalpur, for the third week from Peshawar, for the fourth week from Kohat and again for the next two weeks from Risalpur and so on. Risalpur is about 25 miles to the ENE of Peshawar and Kohat 30 miles to the south. The heights above sea level of the aerodromes at Risalpur, Peshawar and Kohat are 320 m., 350 m. and 535 m. respectively.

Each aeroplane is provided with an altimeter with trade scale. This gives the correct heights when the mean temperature of the air column is 50°F. For other temperatures, these heights must first be corrected for the deviation of the mean

temperature of the air column from 50° F. Before the ascent the altimeters are set so as to read zero at the level of the aerodrome and readings of the dry and wet bulb thermometers are taken at heights of 1000, 2000, etc., feet above ground as read by the altimeter.

From 1st April 1927, aeroplane aneroids were brought into use in the aeroplanes and these were read along with the dry and wet bulb thermometers. All these aneroids had their scale corrections determined at Agra The aneroid was carried in the rear cockpit The readings of these were periodically checked by comparison with a mercury barometer.

Up to April 1927 all heights were calculated from the altimeter readings. From April, for a few days in each month, the heights were calculated also from the aneroid readings and compared with the corresponding altimeter heights The comparison showed that although on individual days the heights calculated by the two methods showed wide deviations, particularly at Risalpur, the mean differences for any month were small Also the differences between the altimeter and the aneroid readings followed no definite rule, being positive on some days and negative on other days Hence the altimeter readings were taken as correct and up to the end of June 1929 all the heights were calculated from the readings of the aeroplane altimeters

The heights as read by the altimeters were corrected from tables for the mean temperature of the air column calculated from the dry bulb readings and reduced to heights above mean sea level The heights in feet and the corresponding temperatures in °F were converted graphically into kilometres and °A (273 +°C) respectively The values of relative humidity at different levels were obtained from the Aspirations Psychrometer Tafeln For convenience, five relative humidity nomograms were prepared for pressures of 755, 675, 600, 530 and 440 mm. corresponding to heights of 0, 1·0, 2 0, 3 0 and 4 5 km above sea level respectively and the relative humidity at different heights was read out from the nomogram for the nearest height.

From the temperature-height and humidity-height curves, the daily values of temperature and relative humidity at 0 5, 1 0, 1 5, etc , km. above sea level were tabulated and the mean monthly values of temperature and relative humidity for each height calculated. For securing some homogeneity of data, only values obtained from ascents starting between 8 and 11 hrs. were utilized for the purpose of obtaining the mean values

Upper air isotherms at 2° intervals were drawn for each month from the daily temperature readings

In July 1929 the method of working out of the aeroplane data was modified and some improvements were effected so as to secure greater accuracy. The calculation of heights from the altimeter readings was given up except on days when no aneroid readings were available Heights were calculated from the readings of the aeroplane aneroids Arrangements were made for taking readings of the thermometers and the aneroid both during ascent and descent and the mean values were taken.

The aneroid readings were first corrected and the corresponding heights in metres were taken directly from special tables prepared for the purpose. These heights were then corrected for the mean temperature of the air column. The temperatures also were directly converted to °C from conversion tables and mean temperatures and relative humidities from different heights were calculated as before.

All readings of a doubtful nature were rejected. Whenever the pressure readings taken during ascent and descent showed differences of 20 mb. or more, the readings were rejected. In other cases, the means of the two readings were taken.

TABLE I.

Number of observations used for calculating mean monthly temperatures

Ht in Km	Jan	Feb	March	April	May.	June	July	Aug	Sep	Oct	Nov.	Dec
4 5	21	23	10	38	33	10	3	12	27	31	32	13
4 0 ..	30	44	44	46	58	37	33	29	48	62	57	20
3·5 ..	43	57	49	52	65	41	38	39	56	68	69	36
3 0	48	61	50	57	67	41	41	42	58	69	70	45
2 5	50	65	53	57	67	41	41	45	59	70	71	46
2 0	51	68	53	58	67	41	41	45	59	70	71	46
1 5	54	68	53	58	67	41	41	48	59	70	71	46
1 0	54	68	53	58	67	41	41	48	59	70	71	46
0 5	36	43	26	42	50	27	30	36	44	54	46	35
Surface*	36	44	26	42	50	27	30	36	44	54	46	35
Surface†	54	69	53	58	67	41	41	48	59	70	71	46

Table I gives the number of observations used at each height for calculating mean monthly temperatures and relative humidities

TABLE II.

Distribution of the observations according to the time of ascent

Time of taking off	Jan	Feb	March	April	May.	June	July	Aug	Sep	Oct	Nov	Dec
8-9 hrs	2	2		8	30	22	19	24	24	15	20	6
9-10 ,,	13	30	24	28	24	12	15	17	20	24	29	10
10 11 ,,	39	37	29	22	13	7	7	7	15	31	22	30

Table II shows the distribution of the observations used in calculating the means according to the time of taking off of the aeroplanes. As will be seen from the tables the general tendency is for the time of ascent to be later in the winter months—the most frequent time for ascents in the winter months being between 9 and 11 hours and in the summer and monsoon, between 8 and 10 hours

* Excluding surface observations at Kohat.

† Including Kohat observations.

Table III.

Mean monthly temperatures over Peshawar (200 +) °A.

Ht. in Km.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Range.
4·5	58·5	61 0	62·5	70 8	75 3	77 6	78 0	80·4	75·8	72·1	67·6	64·0	21·9
4·0	63·1	63 7	68 8	74 3	78·7	81 3	81·1	82 2	79·0	75·0	71·5	67·3	19·1
3·5	66·3	66 8	72 3	78 0	82 2	84 4	84 3	84·7	82·5	78·4	74·6	70·9	18·4
3·0	69·5	70 0	75 9	81 4	85 9	87·7	87·5	87·6	85·7	82·2	77 9	73·2	18·2
2·5	72·7	73 4	79 4	85 1	89 8	91 8	91 0	90 3	89 1	85·9	81 3	76·2	19·1
2 0	75 8	76 6	83 0	88 7	93 1	95 7	94 3	93·5	91·6	89 6	84·6	79·3	19·9
1 5	79 0	79 9	86 0	92 3	96 6	98·9	97·3	96 4	95·8	93 3	87·6	82 3	19·9
1 0	81 6	82 5	88 9	95 6	99 6	102·7	100 5	99 3	98·7	96·1	90·0	85·0	21·1
0 5	82·5	83 6	89 8	97 3	102 2	104·4	102 7	101·5	100·0	97·5	89·0	86·5	21·9
Surface*.	82·7	83 9	91 2	99 4	103·1	105 2	104 1	102 4	100·7	98·0	88·8	86·4	22·5
Surface.†	83 3	84 8	92 8	98 8	103 2	106 0	104 6	102 7	101·3	98·1	90·8	86·5	22·7

Table III gives the mean monthly temperatures at the surface and at different heights above sea level The lowest mean temperature at all heights was recorded in January. The values for February are, however, nearly as low, being within 1°C of the values for January at all heights except 4·5 km.

The highest mean temperature at the surface was recorded in June, being 32°C correct to the nearest degree Up to 2·5 km June continues to be the hottest month. From 3·0 to 4 5 km the temperatures are practically the same in June and July, the difference being only 0·2°C From the surface up to 2·5 km. the temperature is lower in August than in June and July. At 3 km the temperature is practically the same in June, July and August and above this height the temperatures are highest in August The lower temperature up to 2·5 km. in August compared with June or July is mainly due to the lowering of the temperatures produced by monsoon rains, and the occurrence of the maximum temperature in the same month above 3 km is due to the fact that the lapse-rates in this month approach the saturation adiabatic and hence are lower than in June and July when the atmosphere is comparatively dry

Kohat is 0·53 km above sea level, hence in calculating the mean temperatures at the surface in the above tables, the Kohat surface values have not been included. For comparison, the mean values of temperature at the surface have also been calculated including the surface values for Kohat It is found that except in April the effect of adding the Kohat values s to cause a distinct rise in the value of the mean surface temperature

*Excluding surface observations at Kohat.
†Including surface observatins at Kohat.

Fig. 1 shows the mean monthly temperatures over Peshawar and *Fig. 3 (a-c)* shows typical isopleths of temperature over Peshawar during February, May and October. It will be seen that the day to day variations of temperature are very large in February. In May the variations are smaller and the period of the hot and cold waves is generally much longer than in February. In October, the variation in temperature from one day to another is very small.

The annual range of temperature decreases from the surface upwards becoming a minimum at 3 km. and again increases in value above this height. The range at 4·5 km. is nearly as great as at the surface. It may be mentioned, however, that the number of observations falls off above 3 km and is rather small at 4·5 km. compared with other heights. In spite of this, the existence of the effect is unmistakable.

TABLE IV

Extreme values of temperature recorded over Peshawar (200 +) °A.

Ht. in Km	Jan		Feb		March		April		May		June		July		Aug		Sep		Oct		Nov.		Dec.	
	X	N	X	N	X	N	X	N	X	N	X	N	X	N	X	N	X	N	X	N	X	N	X	N
4·5	67	51	73	54	67	55	79	64	84	69	81	74	81	75	83	77	83	69	79	67	73	63	73	55
4·0	72	53	75	57	75	58	81	67	85	73	88	76	87	71	86	77	86	72	81	70	78	66	75	59
3·5	77	58	79	56	80	62	84	71	89	77	93	79	89	77	89	80	88	77	84	73	81	66	79	63
3·0	80	62	81	60	84	66	88	73	92	80	96	83	92	81	91	84	92	81	88	77	84	69	81	65
2·5	80	61	85	63	89	71	92	77	96	83	97	86	96	84	95	85	95	83	91	80	87	73	83	68
2·0	81	66	87	65	93	74	95	80	101	86	100	87	101	87	98	89	99	86	96	83	89	78	86	73
1·5	85	70	91	69	94	77	99	83	104	89	103	93	102	92	101	92	103	90	99	87	92	80	89	76
1·0	87	74	92	71	99	80	102	85	108	91	107	97	107	95	105	93	106	92	101	91	95	81	93	79

The extreme values of temperature recorded at different heights over Peshawar are given in *Table IV* The values for the surface and 0·5 km above sea level have not been given since these vary very much with the time of observation

The highest temperature at 1 km was recorded in May, the value being 35°C and the lowest temperature at the same height was recorded in February, the value being—2°C. The monthly range of temperature (*i e*, highest temperature —lowest temperature during the month within the time of observations) was greatest at all heights in February, its value for different heights during this month varying from 19° to 23°C. The value of the monthly range of temperature is high in all the winter months November to March, but decreases after March, reaching its minimum value in August. During this month, its value at different heights varies from 6° to 10°C. After August the value again increases.

The annual range of temperature (*i e*, the difference between the highest and lowest temperatures recorded during the year at the time of observations) does not show any appreciable variation with height but is more or less constant at all heights, the value being about 36°C.

It may be mentioned that the values given in the above table are merely the extreme values recorded during observations, that is between 8 and 11 hrs. It is quite possible that the values given, especially for the higher levels, are not the true extreme values, as readings may not be available at these heights on days when the temperatures were exceptionally abnormal due to unfavourable weather conditions. For instance the lowest value at 2·5 km. in January is shown as 61° while at 3 km it is shown as 62°. This does not mean that the lowest temperature at 3 km was actually 62°, but only that on the day when the temperature of 61° was recorded at 2·5 km the plane did not go up to 3 km.

TABLE V.

Mean monthly lapse-rates in degrees Centigrade per km

Ht. in Km.	Jan	Feb	March	April	May.	June.	July	Aug	Sep	Oct	Nov	Dec
4·0—4·5	6·6	5·7	6·4	6·6	6·8	6·1	5·5	4·4	6·5	6·1	6·6	6·4
3·5—4·0	7·1	6·7	7·2	7·4	6·4	6·4	6·4	5·4	7·4	7·1	6·7	5·4
3·0—3·5	7·2	6·3	7·2	7·2	7·8	6·6	6·4	5·8	6·4	7·6	6·8	5·6
2·5—3·0	6·9	7·0	7·0	7·4	7·8	8·2	7·0	5·4	6·8	7·4	6·6	6·0
2·0—2·5	6·9	6·5	7·2	7·2	6·6	7·8	6·6	6·4	5·0	7·6	6·6	6·4
1·5—2·0	6·4	6·6	6·0	7·2	7·0	6·4	6·0	5·8	8·4	7·4	6·2	6·0
1·0—1·5	5·2	5·2	5·8	6·4	6·0	7·6	6·0	6·0	6·0	5·6	4·8	5·4
0·5—1·0	3·4	3·3	6·2	5·3	5·7	4·8	6·3	5·3	3·7	3·4	1·2	3·1
Surface—0·5 (0·33)	1·2	1·8	8·2	12·3	5·3	4·7	8·2	5·3	4·1	2·9	-1·2	—0·6

The general tendency in all the months except March and April is for the lapse-rate to increase in value from the surface upwards, reaching a maximum at about 3 km and then decrease slowly. In March and April, however, the lapse-rates decrease from the surface upwards reaching a minimum between 1 and 1·5 km. Above this height, the lapse-rate increases with height up to 3 km and then shows a tendency to decrease. The tendency to decreasing lapse-rates in the highest layers is not so evident in November, December and January. The lapse-rates are comparatively small between 5° and 6°C per km during August when the monsoon is most active. Results of sounding balloon ascents at Agra show that at times when the monsoon is active the temperature decreases with height practically following the saturation adiabatic. The low lapse-rates generally up to 1 km during the period September to February are connected with the ground inversion at night. As the flights were generally made at about 9 hrs the effect of the night inversion may be expected to be present to some extent. The lowering of lapse-rates near the surface is strongest during November and December. In these two months there is an increase of temperature from the surface up to 0·5 km. The lapse-rates are highest during the hot dry summer months April to June.

Inversions are met with near the surface during the winter months. In other seasons too these may be present, particularly very near the surface and at night and the early mornings. But their thickness is less than those of the winter months and they are generally lost sight of since there are no readings of temperature between the ground and 1,000 ft. above.

TABLE VI.

Mean monthly relative humidities at different heights

Ht in Km	Jan	Feb	March.	April	May	June	July	Aug	Sept	Oct	Nov.	Dec.
4·5	53	49	55	60	55	57	40	73	57	63	55	51
4·0	54	60	57	55	49	50	65	77	62	47	52	49
3·5	58	57	54	48	42	49	64	73	59	41	46	48
3·0	58	58	51	45	42	50	69	71	61	37	43	48
2·5	55	58	47	45	40	50	68	76	61	39	39	41
2·0	53	53	43	38	35	43	68	76	57	35	37	41
1·5	47	47	42	36	32	42	65	75	54	33	34	39
1·0	48	49	44	35	30	37	60	73	49	33	35	39
0·5	52	62	50	41	33	39	58	71	54	36	42	45
Surface	57	67	52	41	35	40	56	70	56	41	47	50

The relative humidity shows a double oscillation during the year, the periods of maxima are January-February and July-August. August is the month of maximum humidity at all levels. In July, the humidity increases from the surface upwards becoming constant above about 2 km.

In all except the monsoon months there is a region of minimum humidity at about 1 km. The relative humidity is a minimum at all levels during May.

TABLE VII

Mean monthly vapour pressures in mm. of mercury.

Ht. in Km	Jan.	Feb.	March.	April	May	June.	July	Aug	Sep	Oct.	Nov.	Dec.
4·5	0·7	0·8	1·0	2·3	3·0	3·6	2·6	5·6	3·2	2·7	1·6	1·1
4·0	1·1	1·2	1·8	2·8	3·4	4·1	5·3	6·7	4·3	2·5	2·1	1·4
3·5	1·5	1·6	2·3	3·1	3·7	5·0	6·4	7·5	5·7	2·7	2·3	1·8
3·0	2·0	2·1	2·9	3·7	4·7	6·3	8·5	8·8	6·7	3·2	2·8	2·2
2·5	2·5	2·7	3·4	4·7	5·7	8·1	10·5	11·3	8·3	3·9	3·2	2·3
2·0	3·0	3·1	4·0	5·1	6·2	9·0	12·9	13·7	9·1	4·9	3·7	2·9
1·5	3·3	3·5	4·7	6·1	7·0	10·5	14·8	16·2	11·2	5·9	4·2	3·4
1·0	4·0	4·4	6·0	7·2	7·0	11·6	16·3	18·8	12·1	7·0	5·1	4·1
0·5	4·6	5·9	7·2	9·4	10·0	13·5	18·1	20·8	14·5	8·3	5·7	5·2
Surface	5·2	6·6	8·2	10·6	11·2	14·5	19·0	21·6	15·6	9·8	6·3	5·8

Table VII gives the mean monthly vapour pressures at different heights in mm. of mercury. Unlike relative humidity, the monthly mean aqueous vapour pressure shows only one maximum during the year and this occurs in August. The minimum occurs in January.

Quetta data.

The observations at Quetta were mostly made between 6 and 11 hours I. S. T. but as in the case of Peshawar, only the observations made between 8 and 11 hours have been considered here. The data were worked out in the same way as the Peshawar data and the daily values for each half kilometer step were tabulated and the mean values of temperature and relative humidity were calculated from these

TABLE VIII.

Number of observations at each height.

Ht in Km	Jan	Feb	March.	April	May	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec
4·5				..	1	1	1	2	..	1		.
4·0	7	4	7	13	4	9	9	3	8	12	12	5
3·5 ..	28	32	42	54	55	39	37	35	40	40	39	23
3 0	32	38	46	56	56	39	39	38	44	40	42	23
2·5	33	38	48	58	56	39	41	38	44	40	42	24
2·0	34	38	48	58	56	39	41	38	44	40	42	24
Surface (1 68)	34	38	48	58	56	39	41	38	44	40	42	24

TABLE IX.

Distribution of observations according to the time of ascent.

Time of taking off.	Jan	Feb	March.	April.	May	June	July	Aug	Sep.	Oct	Nov	Dec.
8 9 hrs		1	1	6	14	4	13	12	14	8	1	
9 -10 ,,	7	14	23	32	23	22	17	12	17	17	21	9
10 -11 ,,	27	23	24	20	19	13	11	14	13	15	20	15

Table VIII gives the number of observations used at each height for the calculation of mean monthly temperatures and relative humidities at these heights and *Table IX* shows the distribution of the ascents according to the time of taking off of the aeroplanes

TABLE X.

Mean monthly temperatures over Quetta (200 +) °A.

Ht. in Km	Jan	Feb	March	April	May.	June.	July.	Aug.	Sep.	Oct	Nov	Dec.	Range.
4 5					72·5	76 5	78 0	82·7	..	67·3			.
4 0	66 9	70 6	70·7	76·7	79·1	81·4	83 6	86·5	77·7	74·5	71 8	70 0	19 6
3 5	70 0	71 3	75·1	78·5	81·9	86 0	86 6	85·8	82·5	77·7	74 4	71 3	16·6
3·0	72 4	74 2	78·6	82·2	86·4	90·2	90 7	89·5	86 9	81·5	77·5	73·8	18·3
2 5	74 6	77·3	81·7	86·2	90·5	94·4	94·2	93·5	90·9	85·3	81·0	77 2	19·8
2 0	76 1	80·2	85·2	90·3	94·6	98·3	97·6	96·9	94·2	88·7	83·7	79·7	22·2
Surface (1 68)	78 1	81 3	87·8	93·1	97·9	101 7	101 2	99·7	95·8	90·2	84·2	80·5	23·6

Table X gives the mean monthly temperatures over Quetta. The lowest temperature at all heights was recorded in January, the mean temperature at the surface being 5°C From the surface up to 2·5 km the temperature is highest in June, but above this height it is higher in July than in June From 4 km upwards the temperature is highest in August, the reason being the decrease in lapse-rate which occurs during this month particularly at the higher levels *Fig. 2* shows the mean monthly temperatures over Quetta and *Fig 4* (*a-b*) shows isopleths of temperature over Quetta during May and August. The diagrams show that very high lapse-rates, approaching the dry adiabatic value, prevail during May Another prominent feature is the very small day to day variation in temperature compared with Peshawar This is particularly noticeable during August

The annual range of temperature is highest at the surface and decreases with height reaching a minimum value at about 3·5 km Above this height the range of temperature shows a tendency to increase, but due to want of sufficient observations it is not possible to say how far this is real.

TABLE XI.

Extreme values of temperature recorded over Quetta (200+)°A

Ht in km	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov.	Dec.
	X N	X N	X N	X N	X N	X N	X N	X N	X N	X N	X N	X N
4 5					73 73	77 77	78 78	83 83		67 67		
4 0	71 61	73 67	77 63	80 73	81 77	84 79	87 80	87 85	83 75	77 71	[illegible] 67	73 62
3 5	81 61	79 61	81 65	86 67	88 76	89 81	91 83	91 80	87 79	86 71	81 68	77 64
3 0	83 58	80 65	84 67	88 70	91 80	97 85	94 87	94 83	91 83	87 76	85 71	79 67
2 5	85 61	83 66	88 67	92 71	97 84	99 89	[illegible] 88	99 87	95 85	91 79	87 75	83 69
2 0	86 65	88 71	92 69	97 79	101 87	103 94	103 93	101 92	99 89	96 83	89 79	87 72

Table XI gives the extreme values of temperature recorded over Quetta Only the values for 2 km and above have been given The highest temperature at 2 km. was 30°C in June and July and the lowest - 8°C in January As in the case of Peshawar it is found that the monthly range of temperature is high in the winter months November to March and much lower in the other months

TABLE XII.

Mean monthly lapse-rates in degrees Centigrade per km.

Ht in Km.	Jan	Feb.	March	April	May	June	July	Aug	Sep	Oct	Nov.	Dec.
4·0—4·5		.			8 0	8·0	7 0	6 5		6 6		..
3·5—4·0	6·8	4·7	5 4	7 1	9 0	7 8	7 3	6 0	8 3	7 8	6 7	6 0
3·0—3·5	5 2	6·0	7·1	7·4	8 8	8 4	8 0	7·8	8 5	7 6	6 6	5 0
2·5—3·0	4·4	6·4	6·2	8·0	8 4	8 4	7·2	8 0	8 2	7·6	7·0	6·8
2·0—2·5	3·2	6·2	7·2	8·4	8 4	7 8	7·0	7·2	6 8	7·2	5·8	5·2
Surface to 2·0	6·3	3·4	8·1	8·7	10·3	10 6	11·3	8 8	5·0	4 7	1·6	2·6

From November to March the lapse-rates are comparatively small at all heights, but in the other months, especially in the hot dry months April to June, the lapse-rate nearly equals the dry air adiabatic value In May, June and July there is a superadiabatic gradient of temperature from the surface up to 2 km. above sea level There is a slight fall in the lapse-rates during the months of July and August above 3·5 km. As in the case of Peshawar, inversions in the upper air are of rare occurrence over Quetta also up to the limit of height usually reached by aeroplanes.

TABLE XIII.

Mean monthly relative humidities at different heights.

Ht. in km	Jan	Feb	March	April	May	June	July	Aug.	Sep	Oct.	Nov.	Dec
4·0	78	66	64	65		42	41	25	54	59	59	76
3·5	70	60	47	46	36	27	36	40	35	43	46	52
3·0	58	56	41	45	34	27	37	37	30	35	41	50
2·5	50	54	39	40	29	24	37	32	26	31	38	49
2·0	61	52	35	36	24	22	41	33	26	27	30	48
Surface (1·68)	55	50	38	37	23	21	40	33	31	31	35	52

Throughout the year the relative humidities are small at all heights. The values are highest in the winter months December to February and lowest in June.

TABLE XIV.

Mean monthly vapour pressures in mm. of mercury.

Ht in km	Jan	Feb	March	April	May	June	July	Aug.	Sep	Oct	Nov	Dec
4·0 ..	2·1	2·4	2·4	3·9	.	3·5	3·9	2·9	3·4	3·0	2·4	2·7
3·5 ..	2·5	2·5	2·5	3·1	3·1	3·0	4·2	4·4	3·1	2·7	2·3	2·1
3·0 ..	2·5	2·7	2·8	3·9	3·9	4·0	5·6	5·2	3·5	2·9	2·6	2·4
2·5 ..	2·5	3·3	3·3	4·5	4·3	4·6	7·0	5·7	4·0	3·3	2·8	3·0
2·0 ..	3·5	4·0	3·7	5·3	4·7	5·3	9·5	7·4	4·9	3·6	2·9	3·5
Surface ..	3·6	4·2	4·8	6·5	5·4	6·2	11·5	8·7	6·5	4·6	3·5	4·0

Table XIV gives the mean monthly vapour pressures in millimetres of mercury. The value is highest at all levels in July and least during November to February, the values being more or less the same during these three months.

TABLE XV.

Mean monthly differences in temperature between Agra and Peshawar (A—P) in °C.

Ht. in Km.	Jan.	Feb.	March.	April.	May.	June	July	Aug	Sep.	Oct.	Nov	Dec.
4 ..	7	5	5	0	0	0	2	0	0	2	0	7
3 .	7	3	4	1	1	—1	0	0	—1	0	—1	6
2 ..	5	4	4	1	4	0	—2	—1	0	0	—2	5
1 ..	5	5	6	3	6	2	—4	—1	—1	2	—2	2
Surface ..	8	9	10	4	6	6	—3	1	0	3	4	7

Table XV gives the mean monthly differences between the temperatures at different heights over Agra* and those at the corresponding heights over Peshawar to the nearest degree Centigrade. During the period October to May the temperatures are higher at all heights over Agra than over Peshawar. The difference of temperature between the two places is a maximum during December-January when the value varies from 5 to 7°C. From July to September the temperatures are slightly higher over Peshawar than over Agra. It will be seen that in November the temperatures are higher over Peshawar than over Agra. This is probably not real, the apparent abnormality being due to want of sufficient number of observations over Agra.

TABLE XVI.

Mean monthly differences in temperature between Agra and Quetta (A—Q.) in °C.

Ht. in Km.	Jan.	Feb.	March.	April.	May.	June	July.	Aug.	Sep.	Oct.	Nov.	Dec.
4 ..	3	1	3	—3	0	0	—1	—5	1	3	—1	4
3 ..	4	—1	1	0	1	—3	—4	—2	—2	1	0	5
2 ..	5	1	2	0	2	—2	—6	—5	—3	0	—2	4

As in the case of Peshawar, from October to May, the temperatures are generally higher over Agra than over Quetta. The difference in temperature again reaches its maximum value during December-January, the difference amounting to 3 to 5°C in these months. From June to September the temperature is higher over Quetta than over Agra. The difference of temperature between the two places is greatest during July-August when it amounts to about 4°C. The values for 4 Km. in the above table have to be accepted with some caution owing to the comparatively small number of observations over Quetta for this height.

It should be borne in mind, however, that the observations at Quetta and Peshawar were all made between the hours 8-11, while the majority of the sounding balloon ascents at Agra were made in the evening just before sunset. The number of observations are also small. Hence, the values given in the above tables should be accepted with some amount of caution. Some of the conclusions may have to be modified when more data are available.

* K. R. Ramanathan. 'A discussion of the results of sounding balloon ascents at Agra, etc.,' Memoirs of the Ind. Met. Dept. Vol. XXV, Part V, page 189.

Some attempts were made to study the relation between the daily temperatures at different heights over Peshawar and Quetta and wind directions at the corresponding heights obtained from pilot balloon observations at these places on the same days. No clear relation, however, could be found The correlation co-efficients between the daily temperatures at 2 km. and 3 km. over Peshawar and the pressure at 8 hrs. local time on the same days at Skardu (2·29 km.) and Leh (3·5 km.), two hill stations in Kashmir were also worked out for some months. The correlation co-efficients were exceptionally high in some months while no relation could be found in other months. Sufficient systematic work has not yet been done, however, for definite conclusions to be drawn from them. It is hoped to continue these studies at some future date.

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Plate I

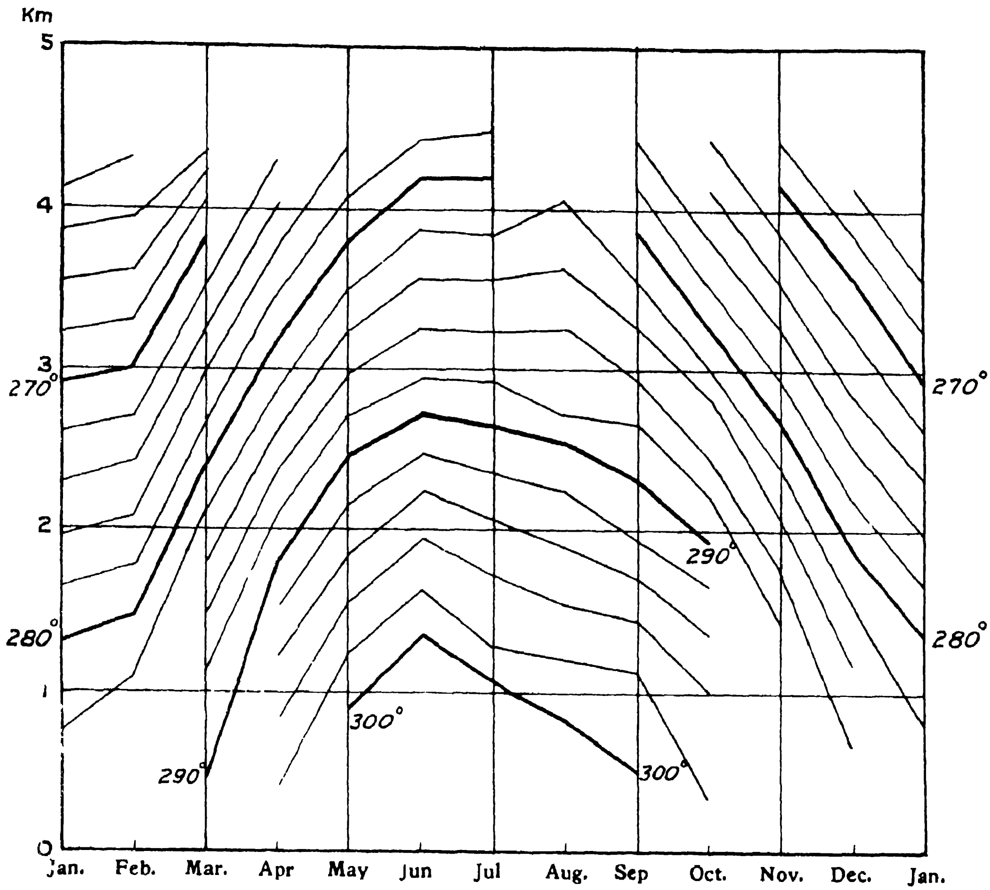


Fig 1 Mean monthly Temperatures over Peshawar (° A)

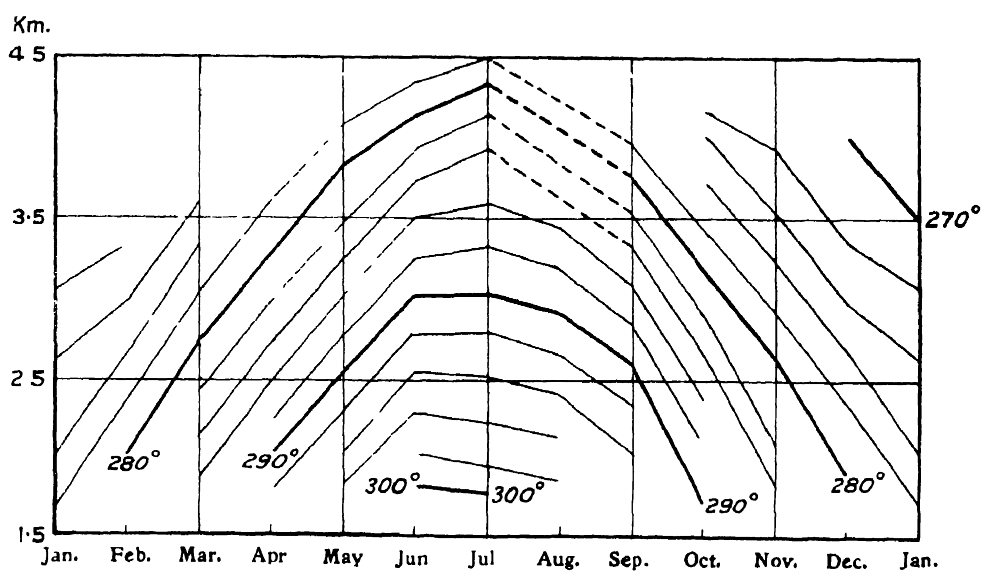
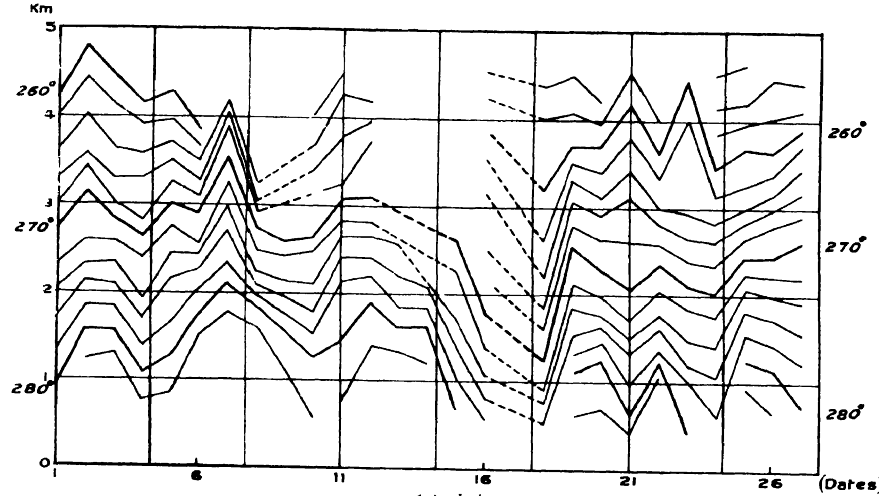
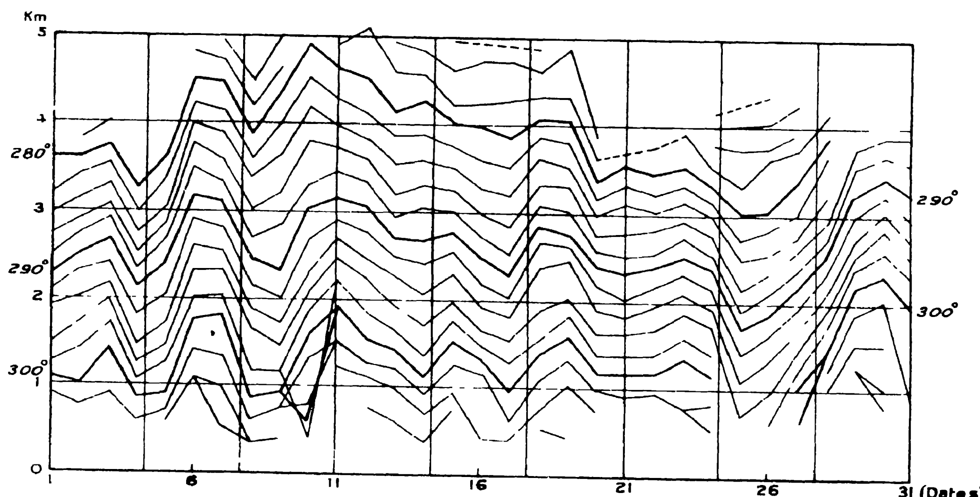


Fig 2 Mean monthly Temperatures over Quetta (° A)

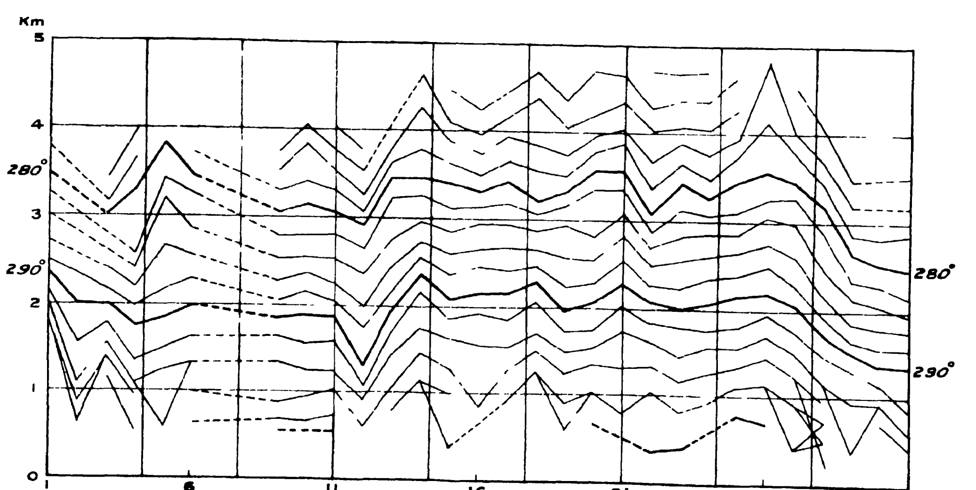
G P 7 O POONA, 1931



(a)- February



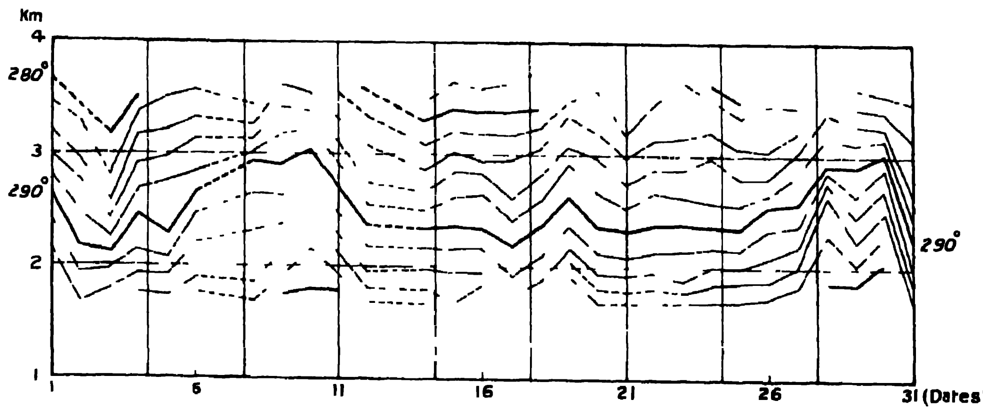
(b)—May



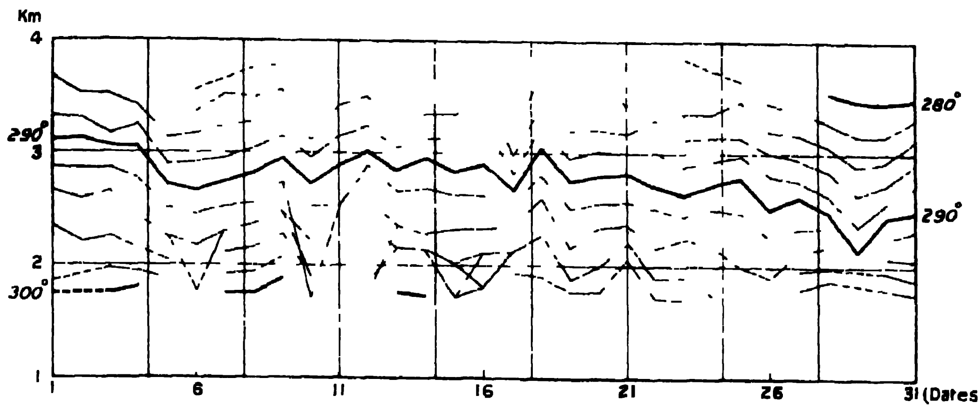
(c)—October

Fig. 3 Isopleths of Temperature over Peshawar (2° intervals)

G P Z O POONA 1931



(a) May



(b) August

Fig 4 Isopleths of Temperature over Quetta (2° intervals)

INDIA

METEOROLOGICAL DEPARTMENT

SCIENTIFIC NOTES

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Rainfall of Siam

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V. DORAISWAMY IYER, B.A.

(Received on 7th February 1931.)

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RAINFALL OF SIAM.

Its normal distribution and relation to Indian rainfall ; possibility of forecasting monsoon rains

BY

V DORAISWAMY IYER B A

(Received on [illegible]th February 1931)

Summary This paper gives the normals of rainfall and of number of rainy days at 73 stations in Siam and discusses briefly the normal distribution of rainfall It is shown by the method of correlation that there is a fairly close relation between the incidence of rainfall in Upper Siam and in North-west India during the monsoon period June to September Correlation coefficients are also given between the rainfall of Upper Siam during the period June to September and the pressure and temperature at various centres of action in the world in the contemporary quarter and the two preceding quarters From these a formula is deduced for a forecast early in June of the monsoon rain of Upper Siam

Introduction.

The daily rainfall data of all the raingauge stations in Siam for the years 2449 to 2466 Buddhist Era corresponding to the Indian financial years* 1906-07 to 1923-24 were very kindly supplied to this department by the Director of Agriculture, Siam, in connection with an investigation into the typhoon which had passed through that country into the Indian area Data for certain selected stations for the years 2467 to 2469 B E (1924 25 to 1926 27) were obtained subsequently through the kindness of the Director General of the Royal Irrigation Department, Siam As the kingdom of Siam is next to India and Burma the most important region which shares with them the bounteous rainfall brought by the southwest monsoon the data have been utilised to obtain an idea of the normal rainfall distribution in that kingdom and to find out the relation between the monsoon rain of Upper Siam and the contemporary rainfall of India While this paper was under preparation the Royal Irrigation Department of Siam published monthly normals of rainfall at the principal stations in the kingdom with monthly maps of rainfall distribution based on the data of the period 1901 to 1924 in their Administration Report for the period 2457 to 2468 B E The normals of rainy days have not however been given in this publication The monthly rainfall maps have been reproduced in a short paper, "Climate of Siam" which appeared in "Siam Nature and Industry"

Geography

2 Siam consists geographically of two distinct portions Upper Siam and Lower Siam Upper Siam constitutes the heart of the Indo-Chinese Peninsula and lies between Burma in the west and the French possessions of Tonkin, Annam and Cambodia in the east southwards it includes the strip of territory between Tenasserim and the Gulf of Siam Lower Siam comprises the portion of the Malay Peninsula lying between Lat 10 N and 6½ N It is a strip of land narrow at the north end and widening out towards the south, consisting roughly of the continuation of the mountain range which bounds Upper Siam on the west, though the range appears in parts as no more than a chain of hillocks

* The Indian financial year begins in April and ends in March.

3. Upper Siam can be divided broadly into the Menam basin and the slightly elevated Korat Plateau in the east. The northern portion of the Menam basin is in general appearance a series of parallel ranges, which, though gently sloping hills in the south, rise into precipitous mountain masses in the north. Between these ranges the Menam and its tributaries form trenches running north and south. The lower Menam basin is an extensive plain, and, together with the region watered by the Meklong on the west and the province of Prachin to the east through which flows the Bang Pakong, forms the central and most fertile portion of Siam. It is flanked on the west by a high mountain range, a continuation of one of the ranges of northern Siam and the boundary between Siam and Burma, which extending further south forms the backbone of the Malay Peninsula. On the east the Dom Pia Fai range, the watershed between the Menam and the Mekong, separates it from the Korat Plateau. The land inclines gently to the sea in the south, and all the three rivers, the Menam, Meklong and Bang Pakong, fall into the Bight of Bangkok. Stretching to the southeast of this inner gulf is a narrow strip of mountainous seaboard forming the districts of Krat and Chantabun, the range which cuts off these districts from Cambodia has peaks rising to 3,000 to 5,000 feet.

4. The Korat plateau is bounded on the west by the Dom Pia Fai range and on the south by the Pnom Dong Rek range, the right bank of the Mekong is also closely flanked by an almost continuous range of hills Hence this part of Siam is practically a basin, the bottom of which is a plain lying from 200 to 300 ft. above sea level, and the sides are hill ranges of about 1,000 to 2,000 ft. elevation. It is drained by some small streams in the north, and by the Nam Mun and its tributaries in the south.

Data.

5. For calculating the normals 70 representative stations which were in existence in 2450 B E (1907-08) were selected and the normals were based on the 20 years' data 2450 B E to 2469 B E (1926-27). Three stations which began their record in 2451 B.E were later added to the list For these stations as well as for seven others which had a break in their records the means based on the actual number of years of data available were reduced to the 20 years' period 2450 to 2469 B E. by comparison with neighbouring stations having data for the full number of years. Figure I gives a map of Siam showing the raingauge stations; their positions were kindly indicated by the Director, Royal Survey Department, Bangkok

6. The normals thus derived, which were in millimeters, were converted into inches in order to make the figures easily comparable with the Indian rainfall data. The number of rainy days was calculated according to the convention adopted in India that a rainy day is one in which 0 1" (2·5 mm.) or more of rain is recorded. Table I (see pages 81 to 84), contains the normals of rainfall and of rainy days in each month. The spelling of station names is that given in the manuscript data received from Siam, it gives the names a more Sanskritic pronunciation than that in general use.

7. The distribution of rainfall and of the number of rainy days in Siam for the two periods, May to October and November to April, are shown in figures 2 to 5. Figure 6 shows the months of maximum rainfall in different parts of the kingdom, and figure 7 exhibits the distribution of average daily intensity of rain for the year

Normal rainfall distribution.

8. *Upper Siam.*—In the whole of Upper Siam the wet season coincides with the period of the prevalence of the southwest monsoon in the Bay of Bengal, and, as in the contiguous country of Lower Burma, lasts from May to October. Owing

however to the action of the frontier hills which the monsoon crosses before reaching Upper Siam it is considerably weaker than in Lower Burma. Thus while the average rainfall of Lower Burma in these months is 121″ and of the Tenasserim division, which adjoins Upper Siam throughout its length, is 159″, that of Upper Siam is only 46″ If we consider only the coastal districts of the Tenasserim division, the contrast between their rainfall, 182″, and that of Upper Siam is as great as that between the rainfall of the Konkan on the Arabian sea and of the adjacent division of the Bombay Deccan from which it is separated by the Western Ghats

9. The striking feature of the monsoon rainfall distribution is that rainfall is least immediately to the east of the frontier hills and increases eastwards as their shielding effect decreases, except where modified by the orographical features of the country. Thus Kanchanaburi and Tak, lying close to the frontier hills, get about 33″, along the Menam basin the amounts recorded generally lie between 40″ and 46″, while in the east of the Korat Plateau Ubol receives 51″ and Sakol Nagor 56″.

10. The patch of heavy rain of 50″ to 60″ on the Menam basin between the parallels of 16°N and 17°N is an effect of the hills which separate the headwaters of the Nam Sak from the Menam The region of heaviest rainfall in Upper Siam is met with on the mountainous seaboard of Chantabun, Chandaburi recording 81″. Another region of heavy rainfall occurs in Prachin, east of Bangkok, near the southwestern slopes of the Pnom Dong Rek range Nagor Nayak 77″, Prachinburi 69″, Saraburi 62″ and Krabindraburi 61″ The shielding effect of the Dom Pia Fai range makes itself felt in the decreased rainfall at Jaiyabhum (33″) and Nagor Rajasima (39″).

11. The rest of the year may be divided into the cold weather period extending from November to February and the hot weather period, March and April. In the cold season most of the rain falls in the month of November , this is evidently due to the persistence of the southwest monsoon in some years and generally to the indraught of humid winds from the neighbouring seas Hence the region round the Gulf of Siam gets more rain than the rest of the country The hot weather thunderstorms on the other hand yield more rain in the Korat plateau and generally in the vicinity of the hills

12. The average annual rainfall of Upper Siam is 51″, and 84 per cent of this amount falls in the months May to October Hence the annual distribution is controlled by and is similar to the monsoon distribution September is generally the rainiest month of the year , at the stations near the northern frontier and in parts of Prachin however the maximum rainfall occurs in August, while the hilly Chantabun coast has the maximum rainfall in an earlier monsoon month Regions near the western border hills have a secondary maximum in May On the west coast of the Gulf, where the late October rains and the rainfall brought by the ' northeast ' monsoon become more important, the maximum of the year is shifted to October at the northern stations and to November at the southern stations. The minimum rainfall of the year occurs in February in the northern provinces and on the west coast of the Gulf of Siam , over the rest of the country the minimum occurs either in December or January.

13. It is interesting to see that the region in India which has the maximum rainfall of the year in September, comprising the eastern districts of the Bombay Deccan and of Mysore together with the Madras Deccan and most of Hyderabad, lies like the similar region in Upper Siam between Lat. 13°N. and 19°N. Another point of similarity in their geography is that both are shut off by mountain ranges from the seas on either side and that the monsoon reaches them only after crossing high mountains to the west. The annual distribution of rainfall in the Deccan plateau has been discussed by Mr. Blanford in his paper on the rainfall of India*

*Indian Meteorological Memoirs, Volume III, pages 32—34.

It may be stated briefly that in both the regions the monsoon current shows its greatest activity only when, though still retaining a high degree of humidity, it loses its strong horizontal velocity and there are more chances for the full development of local instabilities and showers become more intense Further the September rainfall chart of the Climatological Atlas of India shows that during this month the region of greatest rainfall in the Indian area is the Tenasserim coast This indicates that during September as the seat of the barometric minimum becomes less persistent in northern India, there is a relatively larger flow of the monsoon current towards Tenasserim and across the hills there into Upper Siam

14 The coefficient of variability $\frac{\sigma}{N} \times 100$, where $\sigma=$ the standard deviation and $N=$ the normal, of the rainfall during the monsoon months June to September in Upper Siam and in the 32 sub-divisions of India was calculated using the data of the 20 years 1907 to 1926 For the 32 sub-divisions of India, for which data were available for a longer series of years the coefficients based on the data of the 50 years 1875 to 1924 were also worked out They are given in the table below The coefficients from the longer series of years do not differ materially from those based on the shorter period except in northwest India, Malabar and the Madras Deccan It is seen that the variability of rainfall in Upper Siam is small and compares with that in Burma, northeast India and the Central Provinces In the Deccan plateau the variability is nearly twice that in Upper Siam

TABLE II

	Coefficient of variability			Coefficient of variability	
	1907 to 1926	1875 to 1924		1907 to 1926	1875 to 1924
Upper Siam	13		Rajputana, West	50	42
Lower Burma	9	9	Rajputana East	38	30
Upper Burma	9	13	Gujarat	32	28
Assam	9	10	Central India, West	23	20
Bengal	12	12	Central India, East	25	28
Orissa	13	14	Berar	25	26
Chota Nagpur	15	14	Central Provinces, West	15	18
Bihar	18	20	Central Provinces, East	12	14
United Provinces, East	17	23	Konkan	17	18
United Provinces, West	24	24	Bombay Deccan	21	19
Punjab, East and North	31	34	Hyderabad, North	25	25
Punjab, South-West	67	47	Hyderabad, South	27	26
Kashmir	29	19	Mysore ..	21	24
North-West Frontier Province	40	34	Malabar	35	21
Baluchistan .	75	62	Madras, South-East	24	26
Sind ..	83	70	Madras Deccan	19	30
			Madras Coast, North	17	18

15. *Lower Siam.*—In Lower Siam there is a sharp contrast in the annual rainfall distribution between the east and west coasts. The west coast, like the Tenasserim coast further north, is exposed to the full brunt of the Bay monsoon and has its chief rains in the months May to October. The region between Ranong and Bhanga gets the greatest rainfall in the plains, the annual normal at Takuapa being 169", of which 140" or 83% falls in the six months May to October. On the western slopes of the hills near this coast the rainfall is probably even greater. Further south with the southeast trend of the coastline there is a sharp decrease in rainfall.

16. The eastern provinces of Nagor Sri Dharmaraj and Pattani, which lie along the south China Sea, are shielded from the southwest monsoon by the chain of hills which runs through the centre of the Peninsula. They get less than a quarter of their annual fall in the months June to September. The chief rainy months there are October to January, when nearly two-thirds of the annual fall occurs. In these months the northeast winds which prevail in the south China Sea have an oceanic origin like similar winds in the south of the Bay of Bengal. The rainiest month is November except in the southern districts of Pattani where the maximum rainfall occurs in December. The driest month is February. In the seasonal distribution of its rainfall this coast is similar to the east coast of Ceylon which lies in similar latitudes, and has its maximum rainfall in the months of November and December, and somewhat similar to the Coromandel coast where however the rainiest months are October and November.

17. *Average daily intensity of rainfall.*—The average daily intensity of rainfall, which represents the amount of rain that on the average may be expected on a rainy day, was calculated by dividing the annual normal rainfall by the annual number of rainy days. These show that the intensity is greatest, about 1·4", on the coast of the Bay of Bengal between Ranong and Bhanga; it is 1·3" at Khonkaen and is about an inch on the Chantabun coast as well as in the provinces of Prachin and Pattani. The regions of least intensity, 0·7", are met with in the northern provinces of Bayab and Maharashtra, and to the east of the Dom Pia Fai range.

18. Similar figures were also obtained for the different seasons. In the southwest monsoon months the greatest intensity naturally occurs on the coast of the Bay of Bengal, (Takuapa 1·8"), while the lowest intensity is on the opposite coast of of Lower Siam, (Sonkhla 0·5"). In the northeast monsoon months on the other hand the east coast of Lower Siam has the maximum intensity (Pattani 1·5"). In the hot weather the region of maximum intensity is shifted to Rayong (1·5") on the Chantabun coast but Takuapa closely follows it with 1·1". In these seasons the region of minimum intensity lies in the northern provinces.

19. Averaged over the whole of Siam the mean daily intensity on a rainy day is 0·89", this is identical with that of Malabar. The only sub-divisions in India where this figure is exceeded are Lower Burma (1·05") and the Konkan (1·15"). Assam, Bengal, Bihar the United Provinces, Gujarat, Central India and the east Central Provinces very nearly approach Siam in their average daily intensities.

20. *Rainy days with 1 mm. or more of rain.*—The number of rainy days given in Table I, has been calculated on the assumption that a rainy day is one with 0·1" or more of rain. As the rainfall has been recorded in millimeters the number of days of rain of 1 mm. or more was also calculated for 14 selected stations for the sake of comparison with the other figures. Both the values of rainy days are given in Table III, (page 85). These indicate that light rain between 1 mm. (0·01") and 2·5 mm. (0·10") occurs on the average on 13 days in the year near the head of the Bight of Bangkok and on 6 to 10 days at the coast stations on the Gulf of Siam and the south China sea. At Khonkaen there are only two days of such falls. Elsewhere the number of days of falls between 1 mm. and 2·5 mm. varies between 4 and 8.

Comparison of monsoon rain in Upper Siam with monsoon rain in India

21. With a view to compare the monsoon rainfall in Upper Siam with the contemporary rainfall in India the mean rainfall of Upper Siam based on the data of 52 stations was calculated for the accepted monsoon season in India, June to September, for each of the years 1907 to 1926 The normal rainfall for these months is 32·5″. The departures from normal for each of the years is given below :—

TABLE IV.

—	0	1	2	3	4	5	6	7	8	9
1900+ ..		..	..	..	..	.	..	—4·7	+7·2	+6·5
1910+ ..	+1·3	—1·7	—1·2	—3·9	—1·1	—0·9	+2·6	+6·1	—2·1	—4·6
1920+ ..	—3·7	+1·5	+1·0	—3·8	+1·2	—3·7	+3·9	..	..	..

22. The above data were then correlated with the departures of the contemporary monsoon rainfall of the 32 sub-divisions of India. The coefficients obtained are given in Table V and are plotted in figure 8

TABLE V.

Correlation coefficients of Upper Siam rainfall, June to September, with the contemporary rainfall of:

Lower Burma	— 0·24	Rajputana East	+ ***0·63***
Upper Burma	+ 0·41	Gujarat	+ 0·40
Assam	— 0·07	Central India West	+ 0·36
Bengal	+ 0·13	Central India East	+ 0·42
Orissa	+ 0·04	Berar	+ 0·48
Chota Nagpur	— 0·11	C P West	+ 0·34
Bihar	— 0·01	C P East	+ 0·10
U. P. East	+ 0·30	Konkan	+ 0·04
U. P. West	+ 0·36	Bombay Deccan	+ 0·21
Punjab E. and N	+ ***0·69***	Hyderabad, North	+ 0·45
Punjab S W.	+ ***0·60***	Hyderabad, South	+ 0·46
Kashmir	+ ***0·69***	Mysore	+ 0·08
N. W. F. P.	+ ***0·63***	Malabar	— 0·01
Baluchistan	+ 0·25	Madras Southeast	+ 0·47
Sind	+ 0·37	Madras Deccan	+ 0·44
Rajputana West	+ ***0·72***	Madras Coast North	+ 0·40

23. To find out which of the above values may be considered significant we may proceed as follows. It is known that $Z=\frac{1}{2}\log_e\frac{1+r}{1-r}$ varies very nearly according

to the 'normal' law and has a standard error $= \frac{1}{\sqrt{n\text{-}3}}$ where n is the number of values of each of the correlated variables*. Hence if the two variables are uncorrelated, the probable value of Z is $\frac{\cdot 674}{\sqrt{n\text{-}3.}}$. In our case $n = 20$; thus the probable value of $Z = \frac{\cdot 674}{\sqrt{17.}} = .164$. The probable value of the greatest of 32 random values of Z is therefore $\cdot 164 \times 3 \cdot 41 = \cdot 56$, using the table given by Sir Gilbert T. Walker †. The value of r corresponding to this value of Z is ·51 and is the probable value of the greatest of 32 random coefficients between uncorrelated variables. Hence in the above table coefficients which exceed 0·51 may be accepted as indicating a real relationship; they are printed in thick type.

24. It will be seen that the coefficients with most of the subdivisions in northwest India exceed this figure. With North-West India as a whole, which term includes the West United Provinces, the Punjab, Kashmir, the North-West Frontier Province and Rajputana, the coefficient is +·73. With the Peninsula, which term comprises Gujarat, the Central Provinces, the Konkan, the Bombay Deccan, Hyderabad and the north Madras coast, the coefficient is +·49.

25. Northwest India is mainly under the sway of the Arabian Sea branch of the monsoon and conditions which favour its activity there would therefore seem to run parallel with conditions which stimulate the activity of the Bay monsoon in Upper Siam For example one of the stimulating factors is the westward movement of depressions from the head of the Bay of Bengal into northwest India; this is favoured by a more northerly position of the subtropical anticyclone separating the easterly and westerly circulation in the upper air. Such a displacement of the anticyclone over the China Sea area is also presumably favourable for the westward passage of typhoons from the China Sea across the Indo-Chinese peninsula. Higher pressure relatively to the normal over northeast India than over Gujarat is known to be favourable for rain in northwest India Such a pressure distribution, as also one in which pressure is higher, relatively to the normal, over northeast India than over Lower Burma, would tend to deflect the Bay monsoon more towards Upper Siam. This is confirmed by the following correlation coefficients :—

TABLE VI.

	Monsoon rainfall June to September	
	Upper Siam.	N. W India
Pressure gradient June to September.		
Calcutta—Rangoon	+ 51	+ 40
Calcutta—Veraval	+ 54	+ ·69
Lahore—Veraval	+ ·44	+ ·68

26. It is interesting to see that the table of correlation coefficients of the monsoon rainfall of 'India Chief' with the contemporary rainfall of the sub-divisions indicates

* R. A. Fisher: Statistical methods for research workers, 1930, III edition, page 164.
† Indian Meteorological Memoirs, Vol. XXI, Part IX, page 15.

relationships which are similar to the relationships suggested by Table V. Further the monsoon rainfall of the divisions having coefficients of ·4 and above with Upper Siam rain have high mutual correlation coefficients *.

27. It is well known that during the retreating or 'northeast' monsoon season the rainfall of southeast Madras is to a large extent influenced by the position of the seasonal low in the south of the Bay ; a westerly position of the low nearer the Coromandel coast is favourable for rain in the south of the Peninsula, whereas a more easterly position near the south Andaman Sea is unfavourable. Since both southeast Madras and Lower Siam are partly dependent on the moisture coming from the south of the Bay of Bengal, it may be expected that there would be an opposition between the rainfall of these two regions in this season. To test this the correlation coefficient between the rainfall of southeast Madras and of Lower Siam was calculated during each of the months October and November.

TABLE VII.

	Rainfall of southeast Madras.	
	October.	November
Rainfall of		
Lower Siam, west coast	— ·19	+ ·25
Lower Siam, east coast	— ·07	+ ·27
Lower Siam, both coasts	— ·15	+ ·40

In the month of October there is a marked opposition between the rainfall of southeast Madras and that of the Bay of Bengal coast of Lower Siam , but with the rainfall of the east coast of Siam southeast Madras rain has no relation. In the month of November on the other hand there is a positive relation between southeast Madras rain and the rainfall on either coast of Lower Siam. This indicates that with the more southerly position of the seasonal low in this month, the opposition between the land areas on either side of the south of the Bay gives place to sympathy, both the regions benefiting more or less by any northward displacement of the seasonal low.

Forecasting of the monsoon rain of Upper Siam.

28. The fairly close relationship between the rainfall of Upper Siam and that of northwest India during the period June to September suggested that formulæ similar to those in use for the forecasting of the monsoon rain in India might be obtained for foreshadowing the monsoon rain of this region.

29. Accordingly the correlation coefficients were worked out between Upper Siam rain and the quarterly pressure and temperature data of various centres of action, which had shown a relationship with the monsoon rain of Northwest India and the Peninsula. † Table VIII gives the coefficients obtained For the stations included in the pressure centres a reference may be made to Ind. Met Mem., Volume XXIV, Part IV, Chap. II, page 88.

* *Vide* Indian Meteorological Memoirs, Vol. XXV, Part II, page 23, Tables E and F.
† Indian Meteorological Memoirs, Vol. XXIV, Part X, pages 334-5 and 339.

TABLE VIII.

Correlation coefficients of Upper Siam rainfall June to September with:

	Years of data.	Two quarters before Siam.	One quarter before Siam.	Contemporary quarter.
		Dec.—Feb.	March—May.	June—August.
Pressure.				
S. America	20	— 09	+ ***56***	+ ·41
Tashkent	20	— 25	+ ·10	+ ·36
Central Siberia	18	— 07	+ ***·58***	— ·11
Tokio	20	— ·17	— ·11	+ ·28
Manila	19	— 34	— 34	+ ***50***
Honolulu	20	+ 21	+ 34	+ ***·66***
Samoa	20	+ 29	+ 36	+ ***·57***
S. E. Australia	20	— 03	— ·39	— ·14
Port Darwin	20	— 09	— 32	— 38
Batavia	20	— ***·47***	— 29	— ·44
Seychelles	20	— ·33	— ·03	— ·36
Mauritius	20	— 43	— ·28	— ·44
Temperature.				
Dutch Harbour	20	— 13	— ***·47***	— ·13
South Orkneys	17	— ·13	— ·02	+ ·20

30. Applying the Z test as explained in paragraph 23 above we find that the probable value of the highest of 14 random coefficients in each of the quarters in the above table is ·44. In the winter quarter, December to February, there is only one coefficient which exceeds this value, while in each of the other two quarters there are three coefficients above this value. It is seen, however, that the relations in the above table are in the main similar to those obtained for Northwest India and the Peninsula based generally on double the number of years *. Hence the coefficients may be treated with greater confidence than that warranted by the number of years on which they are based.

31. The positive relation exhibited by South America pressure in the 'one quarter before' persists in the contemporary quarter. Omitting March, the pressure of ½ (April+May) used in the Indian forecast formulæ has a coefficient of +0·55.

* *Vide* Ind. Met. Mem., Vol. XXIV, Part X, pages 334-5 and 339.

32. Tashkent pressure has a positive correlation in the contemporary quarter with Upper Siam rain while with Peninsula and Northwest India rain it has a negative correlation.

33. Central Siberia pressure (mean of Irkutsk and Yenisseisk) has a high positive correlation coefficient in the quarter March to May. With individual months, the coefficients are February +·25, March +·44, April +·14, and May +·45.

34. The negative relation with Manila pressure in winter and spring becomes positive in summer. This change is also seen in the coefficients of Manila pressure with Indian rain and forces one to classify this centre as forming part of the Pacific group of the southern oscillation in summer, but of the Indian Ocean group in the previous quarters.

35. The positive relationship with the pressure of Samoa and Honolulu in the contemporary quarter is also seen in the previous quarters but is less marked.

36. The coefficients with pressure in the Indian Ocean are less marked in the 'one quarter before' than in the other quarters, while with pressure at Port Darwin the coefficients are more marked in the spring and summer quarters. With Equatorial pressure *, which is the mean of the pressure at Seychelles and Zanzibar in February and March, at Batavia from January to April and at Port Darwin March to May, the coefficient is — ·42

37. There is a marked negative relation with Dutch Harbour temperature in the previous quarter. With the months December to April the coefficient is —·40, while ½ (March + April) used in the Indian forecast yields —·51

38. The coefficients with the following elements were also calculated :—

Western Himalayas, snowfall accumulation end of May	— ·48
India (whole), pressure May	+ ·23
Seychelles wind, June to September	+ ·38
South Rhodesia rain, previous October to April	— ·35
Cape Town pressure, September to November	+ ·26

The coefficients worked out with Seychelles May wind, and with May rainfall in the Zanzibar district, in Tenasserim, in south Ceylon and at Amini Divi and Seychelles were found to be negligible. Java rain of the previous October to February also showed no relation.

39. It can be seen from what has been said above that the factors to be mainly considered in deriving a forecast formula for Upper Siam rain are South America pressure ½ (April + May), Central Siberia pressure March to May, Western Himalayas snowfall accumulation end of May and Dutch Harbour temperature ½ (March + April). To these may be added the pressure in the quarter March to May at Honolulu and Samoa on account of the improvement of their relationship in the contemporary quarter, and 'equatorial pressure' and south Rhodesia rainfall on account of the fact that they have been used in the forecast formula of Northwest India and may be expected to give satisfactory results with more years of data.

40. The above remarks are subjective, and it appears worth while to apply a test, in which personal bias is eliminated, to find out which factors are likely to prove insignificant in the long run. Such an examination is possible using Fisher's table given

*Ind. Met Mem., Vol. XXIV, Part X, p. 340.

on page 665 of Proceedings of the Royal Society of London, Series A, Volume CXXI 1928). The analysis is given in the following table :—

TABLE IX.

	n	r	ρ
South America pressure	20	+ ·55	0·23
Central Siberia pressure . . .	18	+ ·58	0·23
West Himalayas snow . .	20	— ·48	0·12
Dutch Harbour temperature	20	— ·54	0·22
Honolulu pressure	20	+ ·34	0·00
Samoa pressure . .	20	+ ·36	0·00
Equatorial pressure . . .	20	— ·42	0·00
S. Rhodesia rain . . .	20	— ·35	0·00

n = number of years of data used

r = correlation coefficient.

ρ = is a lower limit to the probable value of the correlation coefficient in the long run, i.e., when the number of years is very large.

We may consider that factors for which ρ=0·00 are likely to prove insignificant in the long run. On this assumption we see that the last four factors will have to be rejected

41. With the other factors the following table is formed :—

TABLE X.

	S. America	Central Siberia.	West Himalayas.	Dutch Harbour.
Siam	+ ·55	+ ·58	— 48	— ·54
South America	..	+ ·21	+ ·04	— ·25
Central Siberia	.	..	— ·52	— ·41
West Himalayas	..	.	..	+ ·34

This gives the formula :—

Siam rain = +·45 (S. America) +·25 (Central Siberia)

—·29 (West Himalayas) —·23 (Dutch Harbour).

and the resulting joint correlation coefficient R is·81.

42. The significance or otherwise of the above correlation coefficient was examined by the method given on page 227 of Fisher's book mentioned previously. The analysis is as follows :—

TABLE XI.

Variance due to	Degrees of freedom.	Sum of squares.	Mean square.	$\frac{1}{2}\log_e$.
Regression formula . .	4	180·4	45·1	1·91
Deviations .	15	90·3	6·00	0·90
Total . .	19	270·7	..	..

The value of Z is $1\cdot01$. The one per cent. point test gives $Z=0\cdot79$ and hence we see that the joint correlation coefficient is significant.

The calculated values with the above formula and the actual values are plotted in figure 9.

43. I wish to express my indebtedness to the Director General of the Royal Irrigation Department, Siam, for kindly supplying me with a part of the rainfall data used in this paper and to the Director of the Royal Survey Department, Bangkok, for giving the positions of the raingauge stations.

Table I.

Rainfall Normals, Siam.

Normal rainfall in inches printed in ordinary type.

Normal number of rainy days printed in italics

	Jan.	Feb	Mar	Apl.	May	June	July	Aug	Sept.	Oct	Nov.	Dec	Year.
1 Chiengrai .	0 48	0 36	0 61	2 33	6 05	7 85	9 46	12 80	8 13	5 33	2 25	1 15	56 80
	1 0	*0 5*	*1 6*	*4 4*	*9 5*	*10 2*	*13 7*	*11 0*	*9 7*	*6 9*	*2 8*	*1 0*	*75 3*
2. Chiengmai .	0 36	0 09	0 96	1 58	6 03	5 08	5 73	9 08	9 48	6 67	2 28	0 53	47·87
	0 9	*0 3*	*1 7*	*2 5*	*8 5*	*9 7*	*10 8*	*12 3*	*12 4*	*7 5*	*3 6*	*1 1*	*71 3*
3. Lambhun	0 31	0	0 81	1 86	5 17	5 15	4 79	6 63	7 93	5 82	2 41	0·35	41·23
	0 3	*0 1*	*1 5*	*2·5*	*6 9*	*7 1*	*7 3*	*8 7*	*8 9*	*6 9*	*2 5*	*0 9*	*53 6*
4 Nan	0 53	0 24	1 53	2 78	6 98	6 60	7 75	12 19	9 11	3 06	1 23	0 28	52 28
	0 7	*0 5*	*2 2*	*3 9*	*8 3*	*7 0*	*11 2*	*12 9*	*10 1*	*1 5*	*1 6*	*0 5*	*63 4*
5 Lampang	0 40	0·13	1 24	1 50	5 22	4 34	6 01	7 16	7 30	4 39	1 24	0·32	39 25
	0 5	*0 3*	*2·1*	*2 3*	*7 3*	*7 7*	*8 5*	*10 9*	*9 7*	*6 3*	*1 7*	*0 7*	*58 0*
6 Prae	0 56	0 20	1 93	2 78	5 30	4 94	6 05	8 78	8 77	3 99	1 65	0 44	45 39
	0 7	*0 7*	*2 7*	*1 1*	*8 7*	*8 9*	*10 7*	*13·3*	*10 7*	*5 8*	*1 9*	*0 6*	*68 8*
7. Utaradith	0 18	0 31	0 97	1 46	6·04	5 95	6 61	8 10	8 78	4 23	1 50	0 14	44 27
	0 3	*0 7*	*1 3*	*2 5*	*8 2*	*8·8*	*10 7*	*10 2*	*11 1*	*6 0*	*2 2*	*0 1*	*62 4*
8. Svangalok	0 40	0 24	1 48	1 78	6 86	5 78	5 81	6 66	11 13	4 70	1 66	0 24	46 74
	0 6	*0 5*	*2 1*	*2 5*	*8 1*	*8 6*	*8 3*	*10 0*	*12 5*	*6 7*	*2 1*	*0 7*	*62 7*
9 Sukhodaya	0 13	0 18	1 06	1 48	5 87	6 38	7 31	7 37	8 95	4 78	2 35	0 15	46·01
	0 3	*0 2*	*1 3*	*2 2*	*6 3*	*7 1*	*7 5*	*7 3*	*8 3*	*1 2*	*2 2*	*0 3*	*47·2*
10. Bisnulok	0 44	0 62	1 34	3 51	6 30	8 53	9 49	11 05	12 36	6 26	1 49	0 30	61·78
	0 5	*1 0*	*1 7*	*3 5*	*8 1*	*9 8*	*12 2*	*12 5*	*13 3*	*7 3*	*2 4*	*0 7*	*73 0*
11. Bichitra	0 48	0 80	1 82	2 84	7 71	8 78	10 05	12 27	13 88	7 19	2 67	0 28	68 77
	0 5	*0 9*	*2 5*	*2 9*	*7 9*	*9 3*	*10 3*	*11 9*	*12 7*	*6 9*	*3 1*	*0 6*	*69 5*
12. Lomsak .	0 52	0 30	2 13	2 57	6 20	7 47	6 98	8 95	10 81	3 61	1 73	0 25	51·52
	0 6	*0 6*	*2 9*	*3 9*	*9 1*	*10 7*	*11 7*	*13 1*	*13 0*	*5 6*	*1 7*	*0·7*	*73·6*
13. Bejraburn .	0·57	0 68	1 53	3 00	6 00	6 98	8 65	8 89	9 97	3 98	1 29	0 26	51·80
	0 6	*1 3*	*2·1*	*3 9*	*8 7*	*10 1*	*11 1*	*12 3*	*12 1*	*6 3*	*1 9*	*0 8*	*71·2*
14 Tak .	0 75	0·13	0 65	0 98	5 43	4 53	3 53	3 48	7 96	7·72	3 85	0 13	39·14
	0 6	*0 3*	*1 1*	*1 7*	*6 1*	*7 5*	*6 4*	*5 3*	*9 7*	*8 7*	*3·5*	*0 3*	*51 2*
15 Kambaeng Bejra.	0 25	0 18	0 79	0 90	5 64	6 43	5 62	7 63	11 60	6 88	2 82	0 15	48·89
	0·6	*0 3*	*1 2*	*1 1*	*6 7*	*7 3*	*7 2*	*8 9*	*9 8*	*6 1*	*2 4*	*0·3*	*51·9*
16. Nagor Svarga	0 16	0 61	1 20	1 99	4 30	4 07	5 50	6 81	9 39	6 00	1 38	0·08	41·49
	0 4	*0 9*	*1 9*	*2 3*	*6 5*	*6 9*	*7 3*	*9 3*	*11 7*	*7·5*	*1 7*	*0·3*	*56 7*
17. Udaya Dhani	0·11	0 68	1 75	2 09	4 81	5 69	6 34	7 14	10 00	7 70	1 97	0·23	48 51
	0 3	*0 6*	*1 9*	*2 3*	*5 7*	*7 3*	*7 8*	*9 3*	*10 4*	*7 3*	*2 0*	*0 5*	*55·4*

TABLE I—*contd.*

	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
18. Jaynad	0 27	0 70	1 01	2 50	5 60	5 34	6·13	7 04	9 80	8 18	2 15	0 19	48 91
	0·3	0 8	1 1	2 5	5 5	5 9	6 3	7 6	9 9	5 6	2 3	0 1	47·9
19. Uttara .	0 27	0 45	1 98	2 69	8 13	8 15	8 19	8 79	7 46	3·69	0 87	0 23	50 90
	0 3	0 9	3 0	3 8	10 9	11 0	9 5	11 9	9 3	4 5	1 3	0 3	66 7
20. Locy .	0 31	0 23	1 15	3 00	6 66	5·88	5 43	6 73	9 02	4 76	1 18	0 18	44 53
	0·7	0 5	2·0	4 1	8 8	9 4	7·9	10 1	11 7	5 8	2 0	0 5	63 5
21. Sakol-Nagor	0·43	0 78	1 51	5 76	9 68	9 59	7 70	12 45	13 32	3 54	0 71	0 01	65 48
	0 5	1 4	2 5	4 9	10 0	9 5	9 9	13 1	11 1	4 1	0 9	0 1	68 0
22. Khon-Kaen .	0 55	0·67	2 78	3 98	8 80	8 36	9 33	11 08	13 64	7 83	1 64	0 16	68 82
	0 6	1 0	2 7	3 5	6 9	7 1	6 8	7 7	9 9	5 3	1 3	0 2	53 0
23. Roi-Etch	0 23	0 81	1 13	3 71	7 54	7 10	7 78	8 33	11 22	3 69	1 02	0 74	53 33
	0 3	0 9	1 8	3 9	8 1	7 9	9 6	9 5	11 7	4 3	0 9	0 5	59 4
24. Ubol	0 22	0 44	1 26	2 77	6 93	8 17	10 56	11 12	12 81	4 47	0 97	0 09	59 81
	0 3	0 7	1 7	4 3	8 7	10 7	12 1	13 6	11 5	5 7	1 7	0 1	74 1
25. Kukhan	0 16	0 40	1 31	4 04	8 39	7 23	8 58	8 09	12 13	5 06	0 94	0 11	56 44
	0 1	0 7	1 9	4 4	8 7	9 0	10 6	9 7	11 9	6 3	1 3	0 3	61 9
26 Surindra	0 21	0 70	1 66	3 54	6 89	8 69	9 84	8 80	12 30	5 39	1 39	0 57	59 98
	0 3	0 9	1 9	3 6	8 5	11 1	11 7	12 5	13 5	7 1	2 0	0 7	73 8
27. Jaiyabhum	0 25	0 47	1 45	4 21	5 79	4 45	4 06	5 33	8 87	4 82	1 38	0 10	41 18
	0 3	1 1	2 1	5 2	8 6	6 1	7 1	8 0	11 3	5 1	1 9	0 1	57 5
28. Buriramya	0 63	1 05	1 98	3 45	8 65	9 20	8 00	8 01	12 51	8 32	2 16	0 43	64 39
	0 7	1 3	2 1	4 1	8 3	9 3	8 1	8 5	13 3	6 2	2 0	0 7	61 6
29. Nagor Rajasima	0 39	1 48	1 63	3 08	7 17	5 26	4 50	6 40	8 66	7 29	1 84	0 39	48 00
	0 6	1 7	2 2	4 3	8 4	8 1	6 9	8 2	11 9	7 9	2 5	0 5	63 2
30. Singaburi .	0 10	0 76	0 96	1 90	5 95	5 11	5 28	6 96	9 30	7 33	1 51	0 35	45 60
	0 3	0 7	1 3	2 6	7 3	7 8	7 5	10 1	11 5	8 7	2 5	0 5	60 8
31 Lobburi	0 20	0 76	1 33	2 21	6 25	5 73	6 66	7 90	11 08	7 01	1 70	0 19	51 11
	0 3	0 9	1 7	2 4	7 9	7 5	8 7	10 1	12 8	8 5	2 1	0 3	63 2
32. Angthong .	0 16	1 28	1 51	1 94	6 79	7 10	7 31	7 35	11 24	7 78	2 32	0 25	55 03
	0·4	1 7	1 7	2 4	8 2	8 9	9 5	10 1	12 5	7 9	2 7	0 6	66 6
33. Saraburi	0·46	0 78	2 08	2 52	7 41	9 97	10 73	11 12	14 86	7 50	2 17	0 47	70 07
	0 5	0 9	1 7	3 1	8 1	10 1	10 5	11 9	12 3	8 1	2 7	0·8	70·7
34. Ayudhya .	0 38	0 74	1 53	2 43	6 70	7 24	8 02	7·80	11 01	7 12	1 72	0 36	55 05
	0 5	1 1	2 1	3 3	8 3	10 1	10 9	11 0	13 5	8 3	2·5	0 5	72 1
35. Pradum Dhani	0 52	0 79	1 28	2 76	6 12	5 55	6 01	6 16	10 40	8 30	2 77	0·56	51 22
	0 7	1 1	1 9	3 9	7 3	8 7	9 6	9 9	12 8	10 1	2 8	1 1	69·9
36. Dhanyaburi ..	0 78	0·61	1 03	2 20	5·57	5 76	7 45	7 43	11 38	8 56	2 28	0 35	53 40
	0·8	0·7	1·1	3·1	6·9	8·1	10·0	10 1	12 9	9 1	2 7	0·9	66·4

• TABLE I—*contd.*

	Jan	Feb	Mar	Apr	May	June	July.	Aug	Sept.	Oct.	Nov.	Dec.	Year.
37 Nagor Nayak	0 47	0 83	1 99	3 08	8 44	11 61	15 18	16·17	16 77	8 65	1 60	0 48	85 27
	0 6	*0 9*	*2 7*	*3 4*	*9 7*	*13 1*	*14 5*	*16 1*	*14 7*	*8 5*	*2 0*	*0 6*	*86 8*
38 Prachinburi	0 26	1 18	2 73	3 40	8 58	10 84	13 24	14 8	14 38	7 40	1 67	0 24	78 90
	0 4	*1 1*	*2 5*	*4 1*	*9 5*	*11 3*	*12 3*	*13 3*	*11 5*	*6 5*	*2 1*	*0 5*	*75 1*
39 Krabinburi	0 14	0 33	2 61	1 83	6 46	11 34	12 36	12 45	11 26	7 23	1 90	0 45	68·36
	0 3	*0 5*	*2 1*	*2 5*	*8 1*	*9 8*	*12 3*	*12 4*	*10 2*	*5 9*	*3 1*	*0 7*	*67 9*
40 Chaxoeng-Sao	0 28	0 70	2 40	2 68	4 81	6 28	6 48	8 10	9 14	8 95	1 98	0 38	52·15
	0 5	*0 9*	*2 9*	*3 1*	*7 5*	*8 5*	*9 5*	*11 5*	*12 1*	*10 1*	*2 9*	*0 7*	*70 2*
41 Jolburi .	0 41	0 76	2 44	2 19	5 33	4 80	6 25	5 44	10 01	9 41	2 62	0·46	50·12
	0 5	*1 1*	*2 7*	*2 7*	*6 9*	*5 [illegible]*	*7 8*	*8 1*	*11 7*	*10 2*	*3 7*	*0 9*	*61 8*
42 Subarnburi .	0 31	1 00	1 84	2 85	5 20	4 33	5 74	5 67	10 87	8 52	2 54	0 21	49 08
	0 5	*1 1*	*1 8*	*2 5*	*6 9*	*6 5*	*7 3*	*8 5*	*12 5*	*8 5*	*2 5*	*0 4*	*59 0*
43 Nagor Pathom	0 13	0 98	1 49	2 43	6 05	5 41	6 16	5 86	10 09	8 06	3 50	0 10	50 56
	0 2	*1 1*	*2 1*	*2 7*	*6 9*	*8 7*	*10 3*	*10 0*	*12 1*	*10 1*	[illegible]	[illegible]	*65 7*
44 Samudr Sagor	0 22	0 89	2 21	2 37	5 70	4 79	5 06	4 76	9 97	10 52	3 86	0 9[illegible]	51·30
	0 5	*1 0*	*2 5*	*2 3*	*[illegible] 1*	*7 3*	*8 0*	*8 2*	*12 1*	*11 3*	*5 1*	*1 1*	*66·5*
45 Minburi	0 63	0 70	1 89	2 20	6 40	5 14	6 19	7 07	11 30	9 49	2 96	1 00	54 77
	0 7	*1 1*	*2 7*	*2 7*	*7 5*	*7 5*	*9 1*	*9 7*	*12 1*	*9 5*	*3 3*	*1 2*	*67 1*
46 Nondaburi	0 41	0 36	0 92	1 58	5 26	4 48	5 86	6 12	8 99	8 93	2 93	0 40	46 24
	0 5	*0 9*	*1 2*	*1 9*	*6 7*	*6 9*	*7 8*	*8 6*	*10 7*	*9 5*	*3 3*	*0 9*	*58 9*
47 Bangkok	0 44	0 68	1 52	1 86	5 47	5 28	6 52	6 97	11 06	10 02	2 98	0 39	53 19
	0 8	*1 2*	*2 1*	*2 7*	*7 3*	*8 5*	*10 2*	*10 4*	*12 8*	*12 1*	*4 1*	*0 9*	*73 1*
48 Dhonburi	0 25	0 65	1 19	1 62	6 76	5 48	7 16	7 21	10 28	9 65	3 07	0 41	53 73
	0 5	*1 1*	*1 5*	*2 7*	*8 5*	*9 7*	*10 3*	*9 9*	*12 5*	*11 7*	*3 6*	*0 6*	*72·6*
49. Phrapradaeng	0 50	0 94	1 36	2 17	6 25	5 76	6 32	6 17	11 60	10 21	3 09	0 63	55·00
	0 7	*1 5*	*1 7*	*2 7*	*6 7*	*6 9*	*7 5*	*7 2*	*11 2*	*9 2*	*3 1*	*1 1*	*59 5*
50 Samudaprakar	0 55	0 74	2 02	2 69	6 92	4 24	6 37	5 51	12 71	9 46	2 36	0 80	54 39
	0 5	*1 1*	*2 5*	*2 9*	*8 4*	*5 7*	*7 5*	*8 7*	*12 3*	*9 9*	*3 1*	*1 1*	*63 5*
51. Kanchanaburi	0 35	0 59	1 11	2 49	5 50	3 74	4 29	3 91	7 59	7 37	3 13	0 25	10 32
	0 3	*0 9*	*1 3*	*2 5*	*5 8*	*4 9*	*5 4*	*5 1*	*5 9*	*6 5*	*2 3*	*0 5*	*41·4*
52 Rajaburi	0 12	0 66	0 87	1 19	5 76	4 94	5 50	4 89	9 35	8 79	3 91	0 31	45 62
	0 3	*0 8*	*1 3*	*2 0*	*7 9*	*8 1*	*8 9*	*8 5*	*11 3*	*9 6*	*3 6*	*0 9*	*63·2*
53. Samudasongram	0 20	0 54	0 56	1 26	6 35	6 46	5 09	5 63	9 14	11 34	5 53	0 45	52 85
	0 3	*0 5*	*0 8*	*1 6*	*6 9*	*6 9*	*6 6*	*7 5*	*9 9*	*9 6*	*3 5*	*0 8*	*54 9*
54. Bejaburi	0 17	0 31	1 52	1 52	6 35	5 82	5 68	6 68	10 06	11 19	6 15	0 99	56 44
	0 3	*0 5*	*1 1*	*1 4*	*6 9*	*8 5*	*5 8*	*9 1*	*11 3*	*9 7*	*3 9*	*1 2*	*62 7*
55 Prachwab-Kirikhan	0 85	1 19	1 36	1 39	3 39	4 50	4 72	3 41	4 48	8 54	4 39	1 39	39 61
	1 1	*1 5*	*2 1*	*1 7*	*4 3*	*7 5*	*6 8*	*6 7*	*6 2*	*9 0*	*4 5*	*1 3*	*52·7*

TABLE I—*concld.*

—	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov.	Dec	Year
56 Rayong	0 83	[illegible] 62	3 38	3 63	7 79	7 82	6 27	4 79	10 64	8 13	4 06	0 69	60 65
	0 9	*1 7*	*2 5*	*2 3*	*8 0*	*7 5*	*6 5*	*5 8*	[illegible]	*7 9*	*3 5*	*1 1*	*57 4*
57 Chandaburi	2 30	1 96	3 65	3 27	9 73	17 39	15 62	15 03	15 73	8 23	2 63	0 92	96 24
	1 8	*1 9*	*1 1*	*1 5*	*10 8*	*15 3*	*11 9*	*15 5*	*15 7*	*10 1*	*3 6*	*1 8*	*100 3*
58 Chumborn	3 21	2 22	2 66	3 53	7 19	7 80	7 16	7 59	7 03	12 52	13 86	5 61	80 88
	3 0	*2 3*	*2 8*	*1 0*	*8 1*	*10* [illegible]	[illegible] *2*	*11 1*	*9 1*	*10* [illegible]	*10 1*	*1 3*	*86 7*
59 Langsuan	3 36	1 76	2 57	2 63	5 02	5 19	5 46	4 31	5 14	9 61	15 48	8 24	68 87
	3 5	*2 1*	*2 6*	*3 2*	*6 3*	*7 5*	*6 9*	*6 9*	*7 7*	*9 7*	*11 7*	*6 5*	*74 7*
60 Ranong	0 37	0 11	2 80	5 07	16 73	28 92	25 65	26 69	23 91	17 56	7 32	1 81	157 24
	0 8	*0 5*	*3 5*	*4 7*	*13 3*	*17 6*	*16 1*	[illegible] *3*	*16 6*	*12 3*	[illegible] *1*	*1 7*	*111 5*
61 Takuapa	1 14	1 35	6 06	7 50	17 60	20 51	23 77	23 95	33 25	21 18	9 23	3 11	168 74
	1 [illegible]	*1 7*	*1 1*	*5 3*	*12·0*	*11 1*	*11 9*	*15 1*	*16 3*	*11 9*	*8 3*	*3 5*	*109 5*
62 Bhanga	2 67	2 54	6 10	9 39	16·30	19 81	21 18	20 59	23 86	18 82	9 74	4 20	155 20
	3 1	*3 1*	*6 1*	*8 7*	*11 9*	*13 5*	*11 6*	*11 1*	*15 9*	*15 7*	*9 5*	*1 3*	*120 8*
63 Krabi	1 32	0 79	2 81	1 07	8 26	10 44	9 96	9 90	11 87	10 73	7 10	3 78	79 93
	2 1	*0 9*	*3 7*	*5 7*	*7 8*	*11 0*	*11 1*	*10 7*	*11 5*	*11 5*	[illegible]	*5 0*	*90 3*
64 Bhuket	1 27	1 53	2 87	5 04	11 69	10 [illegible]	8 53	9 63	12 93	12 36	7 [illegible]	3 06	86 96
	2 5	*1 7*	*3 9*	*6 9*	*12 5*	*11* [illegible]	[illegible] *7*	*12 1*	*11 9*	*13 1*	*10 1*	*1 6*	*105 7*
65 Trang .	2 03	1 00	3 22	6 81	10 87	9 70	9 00	10 68	11 6[illegible]	12 33	8 75	6 19	92 23
	1 3	*1 7*	*3 7*	*7 2*	*10 3*	*9 7*	*8* [illegible]	*9 6*	*11* [illegible]	*10 7*	*9 9*	*6 4*	*93 9*
66 Nakon-Sri Dhamarat	9 67	2 05	3 25	1 39	6 78	5 77	4 26	4 16	6 70	10 86	21 09	18 92	100 90
	9 3	*3 0*	*3 5*	*6 1*	*8 7*	[illegible] *5*	*5* [illegible]	[illegible] *9*	*8 1*	*13 3*	*16* [illegible]	*11 3*	*102·1*
67 Badalung	5 25	0 79	3 20	2 65	2 55	1 73	2 17	2 13	3 02	6 90	18 26	14 19	62 84
	5 8	*1 5*	*3 1*	*3 5*	*4 4*	*3 2*	*1 2*	*5 0*	*1 3*	*8 7*	*13 0*	*11 9*	*68 6*
68 Sonkhla .	6 14	1 76	2 61	2 37	3 06	3 05	2 76	2 76	5 21	8 52	18 61	15 09	71 94
	7 3	*2 2*	*1 0*	*1 2*	*6 3*	*6 0*	*6 9*	*6 8*	*8 5*	*13 4*	*15 5*	*14 2*	*95 4*
69 Pattani	5 60	1 08	2 32	1 39	3 78	1 42	3 82	3 78	4 06	6 70	18 87	16 23	72 05
	6 1	*1 3*	*2 5*	*2 0*	*4 1*	*5 6*	*4* [illegible]	*5 2*	*6 5*	*7 7*	*11 7*	*9 7*	*67 1*
70. Yamu	5 00	1 35	2 14	1 83	3 24	3 80	3 34	1 03	4 72	6 38	20 64	16 28	73 05
	4 9	*1 7*	*1 9*	*2 4*	*1 2*	*5 5*	*1 1*	*1 0*	*5 3*	*7 9*	*12 6*	*10 7*	*65 2*
71 Saiburi ..	5 88	3 85	2 95	2 14	4 52	4 34	3 74	4 28	5 36	8 23	22 91	16 66	84 86
	6 6	*4 6*	*3 0*	*3 1*	*6 1*	*6 8*	*4 7*	*4 9*	*6 9*	*9 6*	*13 1*	*11 7*	*81 3*
72. Yala ..	6 03	2 51	3 39	3 98	6 29	4 79	5 13	5 23	7 38	11 42	15 16	15 31	86 62
	6 1	*2 3*	*3 5*	*4 9*	*7 2*	*5 3*	*5 9*	*6 0*	*8·7*	*11 1*	*13 3*	*11·5*	*85 8*
73. Narathivas ..	9 47	3 18	4 48	3 89	6 48	5 76	6·54	6 55	7 63	10 76	21·58	23 07	109 39
	7·4	*2 7*	*3 3*	*4 1*	*6 9*	*6 5*	*6 7*	*7 0*	*8·4*	*11 9*	*15·6*	*13 7*	*94 2*

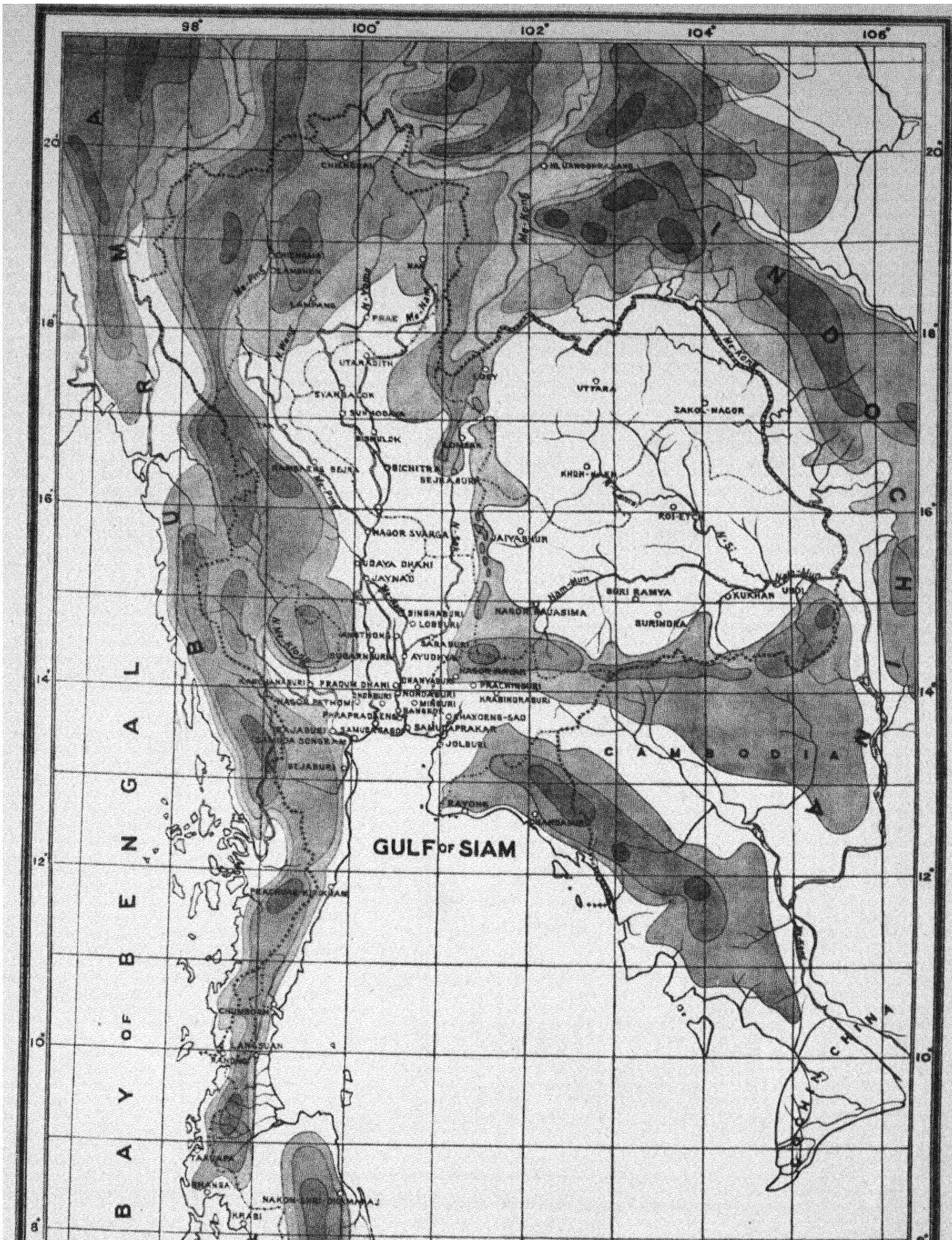
TABLE III.

Normal number of rainy days (0·1" or more) printed in italics.

Normal number of rainy days (1 mm. or more) printed in Heavy Italics.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Chiengrai	1 0	0 5	1 6	1 1	9 5	10 2	13 7	14 0	9 7	6 9	2 8	1 0	75·3
	0	0 6	1 8	4 8	10 5	11 8	15 1	15 5	11 1	7 3	3 2	1 2	83 9
Bisnulok	0 5	1 0	1 7	3 5	8 1	9 8	12 2	12 5	13 3	7 3	2 1	0 7	73 0
	0·7	1 1	2 2	3 5	9 1	11 7	13 7	14 1	14 1	8 2	2 9	1 0	81 3
Tak . .	0 6	0 3	1 1	1 7	6 1	7 5	6 4	5 3	9 7	8 7	3 5	0 3	51 3
	0 9	0 3	1·1	1 7	7 1	8 3	6 7	6 3	9 9	9 7	3 9	0 4	56·3
Nagor Swarga	0 4	0 9	1 9	2 3	6 5	6 9	7 3	9 3	11 7	7 5	1 7	0 3	56 7
	0·4	0 9	1 9	2 5	7 1	7 9	7 9	9 7	12 6	8 1	1 7	0 3	61 0
Khon Kaen	0 6	1 0	2 7	3 5	6 9	7 1	6 8	7 7	9 9	5 3	1 3	0 2	53 2
	0 7	1 1	3 0	3 7	7 0	7 3	6 9	7 9	9 9	5 9	1 3	0 3	55 0
Roi Etch	0 3	0 9	1 8	3 9	8 1	[illegible] 9	9 6	9 5	11 7	1 3	0 9	0 5	59 4
	0 3	1 1	2 0	4 6	9 1	8 [illegible]	10 5	10 2	12 3	4 9	1 0	0 5	65·4
Nagor Nayak	0 6	0 9	2 7	3 1	9 7	13 1	11 5	16 1	11 7	8 5	2 0	0 6	86 8
	0 7	1 1	2 9	3 8	10 5	13 7	15 3	16 9	15 1	9 1	2 2	0 7	91 3
Bangkok .	0 8	1 2	2 1	2 7	[illegible] 3	8 5	10 2	10 4	12 8	12 1	1 1	0 9	73 1
	0 9	1 3	2 6	3 1	8 7	10 0	12 8	12 7	14 5	13 9	4 5	1 4	86 4
Rajaburi .	0 3	0 8	1 3	2 0	7 9	8 1	8 [illegible]	8 5	11 3	9 6	3 6	0 9	63 2
	0 3	0 9	1 7	2 2	9 3	9 9	11 5	11 3	12 9	10 9	4 3	1 3	76 5
Chandaburi	1 8	1 9	1 4	4 5	10 8	15 3	14 9	15 5	15 7	10 1	3 6	1 8	100 3
	1 9	2 1	5 1	5 1	11 7	16 9	15 4	16 6	16 4	11 3	3 9	1 9	108 3
Chumborn .	3 0	2 3	2 8	4 0	8 1	10 1	10 2	11 1	9 1	10 7	10 1	4 3	86 7
	3 9	2 5	2 9	4 2	8 5	11 9	11 0	12 1	10 5	11 4	11 1	5 1	95 1
Takuapa ..	1 7	1 7	1 4	5 3	12 0	11 1	14 9	15 4	16 3	11 9	8 3	3 5	109 5
	1 9	1 8	4 6	5 5	12 3	14 6	15 3	16 0	16 3	12 7	8 7	3 7	113 4
Nakon-Sri-Dhamaraj.	9 3	3 0	3 5	6 1	8 7	7 5	5 7	5 9	8 1	13 3	16 7	14 3	102·1
	9 7	3 5	4 1	6 7	9 9	8 5	6 9	7 0	10 1	14 0	17 5	14 9	112 8
Pattan ..	6 1	1 3	2 5	2 0	1 1	5 6	4 7	5 2	6 5	7 7	11 7	9 7	67·1
	6 6	1 5	2 9	2·2	4 6	6 3	4 6	6 3	7 5	9 1	12 4	10 9	73·7

M20DGofOb,—1-12 31—350—GIPS



98°
100°
102°
104°
106°
20°
18°
16°
14°
12°
10°
8°
6°
BAY OF BENGAL
BURMA
INDO CHINA
CAMBODIA
CHINA
GULF OF SIAM
CHINA SEA
CHIENGMAI
LAMPANG
PRAE
NAN
UTARADITH
SUKHODAYA
PHICHITRA
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JAYNAD
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SAKOL NAGOR
KHON-KAEN
NAGOR RAJASIMA
BURI RAMYA
SURINDRA
UBOL
RAYONG
CHUMPON
LANASUAN
TAKUAPA
KRABI
PHUKET
NAKON-SRI-DHAMARAJ
SONKHLA
PATTANI
SAIBURI
Me-Kong
Nam-Mun
CONTOURS
M
2000
1000
500
200
0

MAP OF SIAM

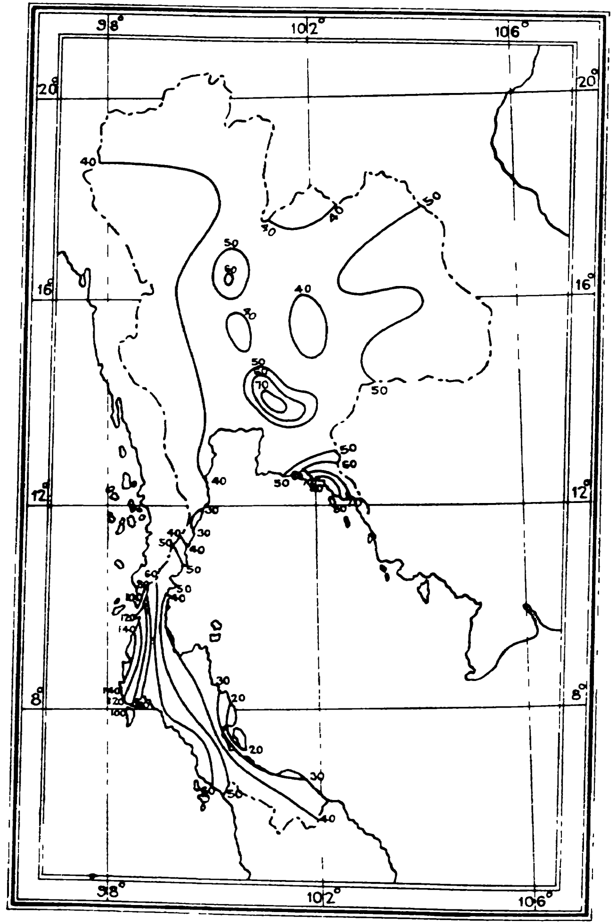

Fig 2 Rainfall in inches, May to October

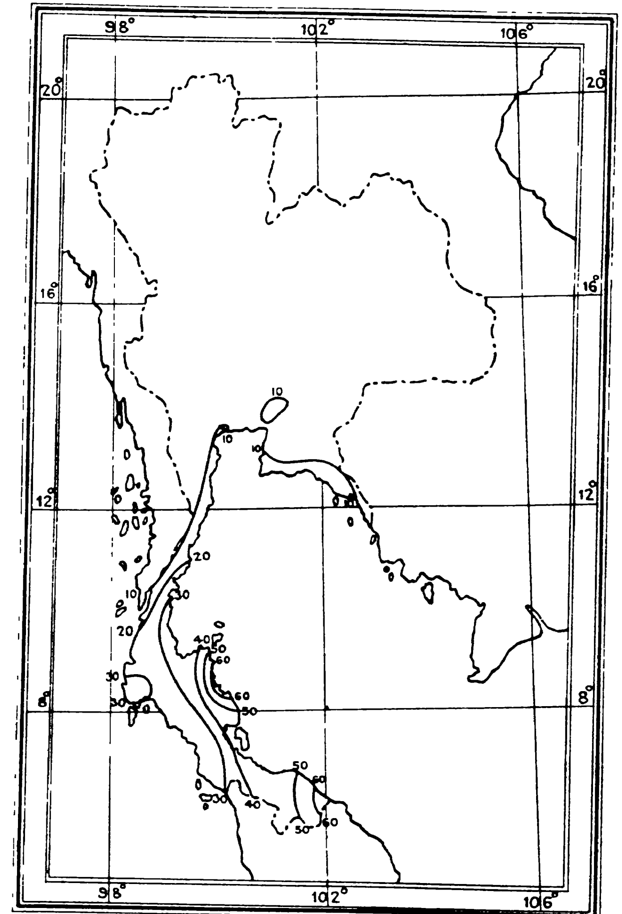

Fig 3 Rainfall in inches, November to April

G P Z O 1931

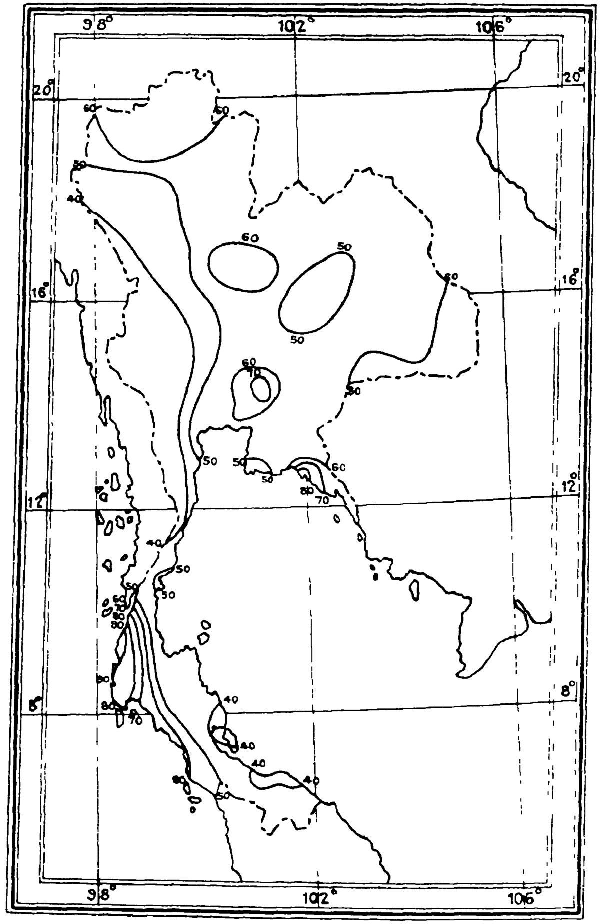

Fig 4 Number of rainy days, May to October

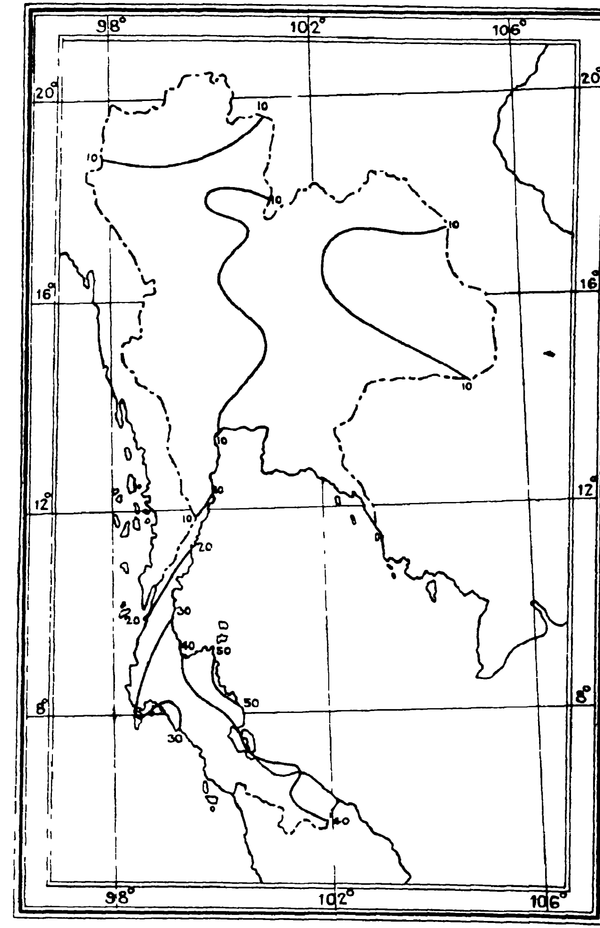

Fig 5 Number of rainy days, November to April

G P Z O POONA 1931

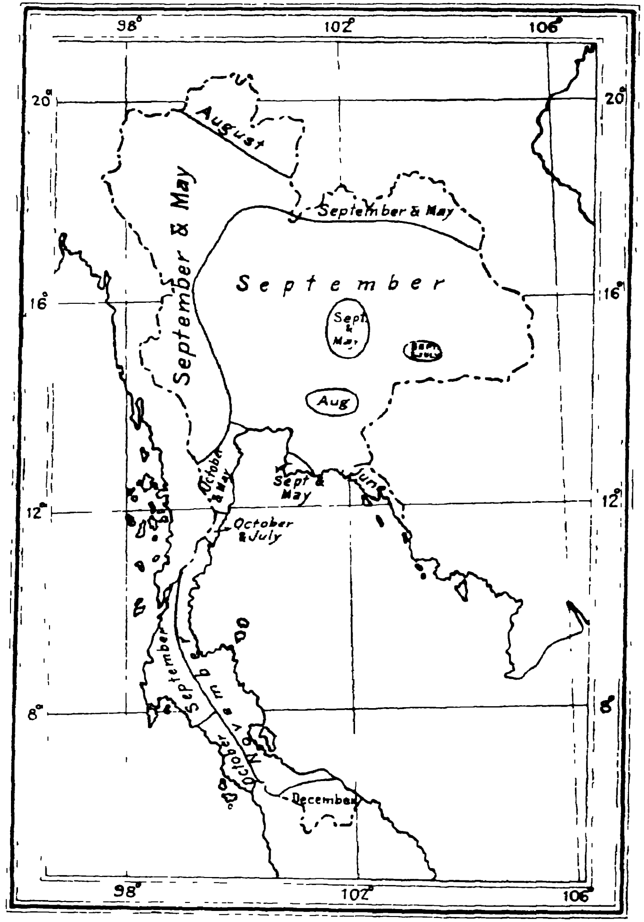

Fig 6 Months of maximum rainfall

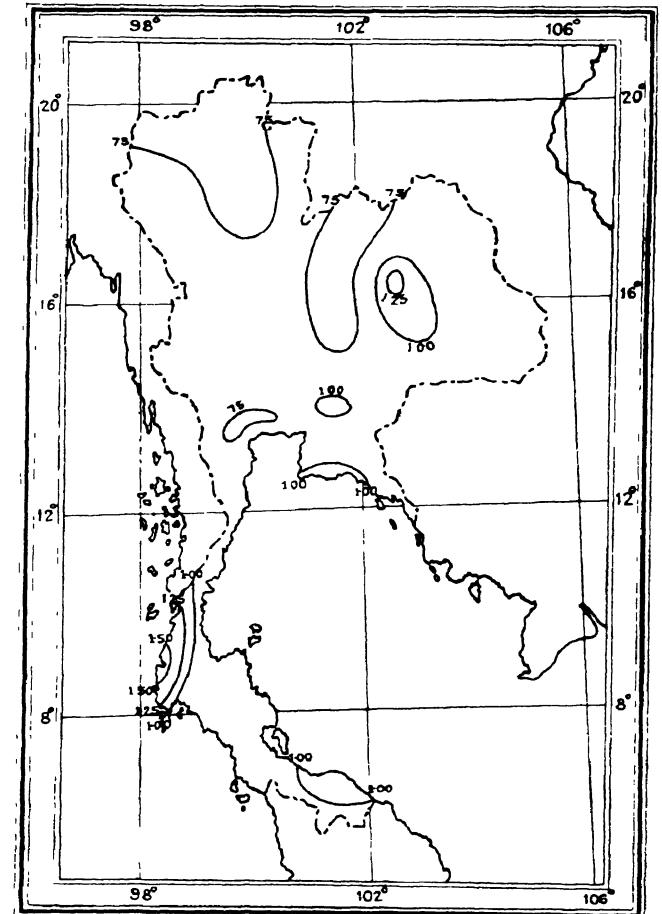

Fig 7 Average daily intensity of rainfall on a rainy day

G P Z O 1931

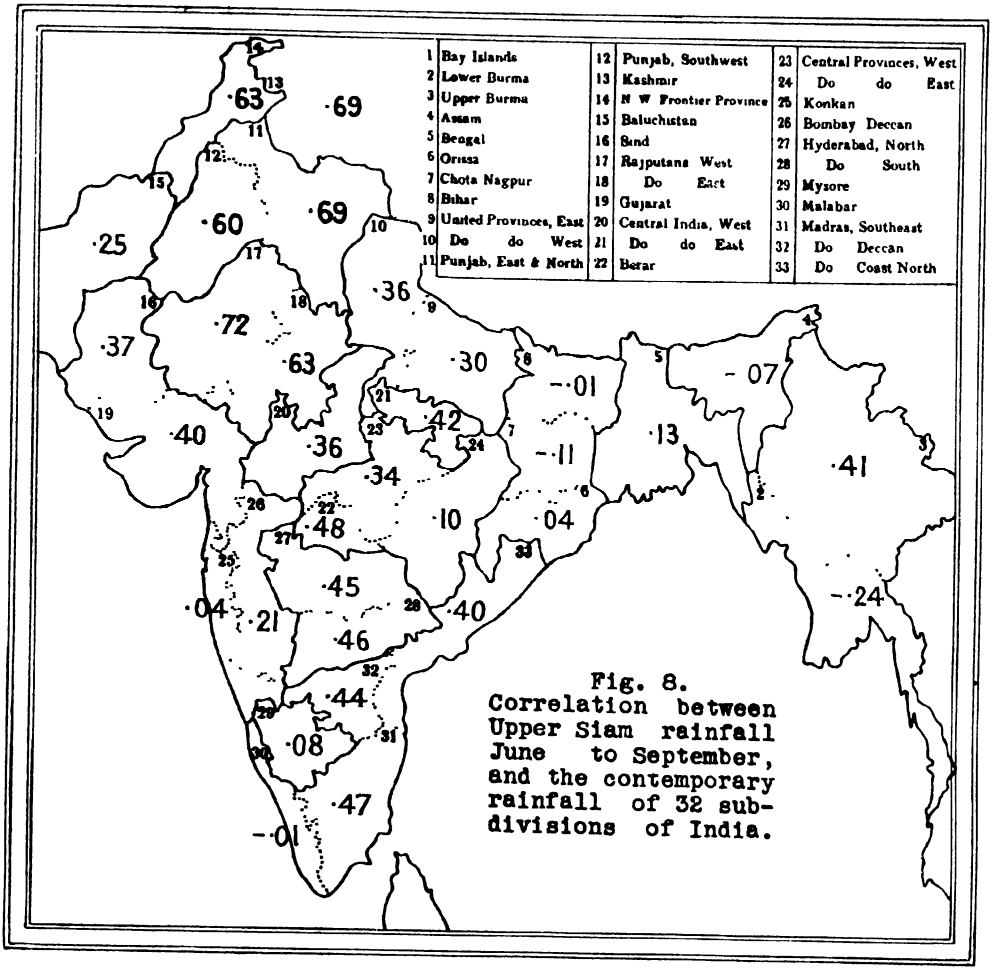

Fig. 8.
Correlation between Upper Siam rainfall June to September, and the contemporary rainfall of 32 sub-divisions of India.

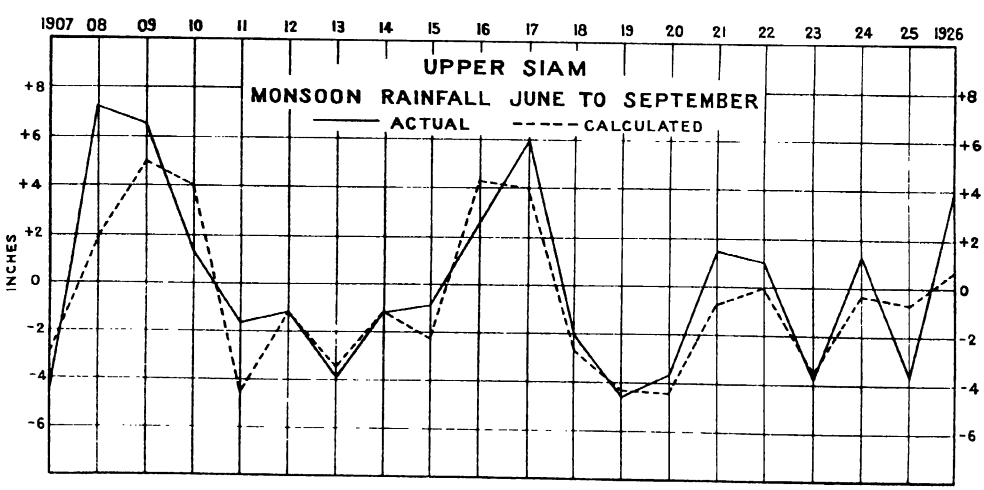

FIG. 9

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BY

G. CHATTERJEE, M.Sc. and P. M. Neogi, B.Sc.

(*Received on 8th May 1931.*)

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CONTRIVANCES FOR LIFTING THE PENS OFF THE RECORDING PLATE OF THE DINES' BALLOON METEOROGRAPH DURING ITS DESCENT.

BY

G. CHATTERJEE, M. Sc. AND P. M. NEOGI, B. Sc.

(*Received on 8th May 1931.*)

The pens of the Dines' balloon meteorograph remain in contact with the recording plate when the instrument strikes the ground at the end of its descent ; invariably, therefore, there is a blur which obliterates a part of the lower portion of the trace. The portion of the record thus lost is found sometimes to cover a height of even half a kilometer above surface The humidity calibration lines are also occasionally covered up entirely by the blur caused by the hair hygrometer pen, especially if these lines are not long enough

For reasons stated above, it was considered advantageous to develop a mechanism to lift the recording pens off the plate at some height above ground during the descent of the instrument Various contrivances were tried off and on during the last three years but those described below have been found satisfactory and simple The devices will be referred to hereafter as " pen releases " Two types of " pen release " have been devised, one for use with instruments which are intended to reach as high as possible and the other with those intended to reach only a predetermined height—usually up to six kilometers

The first type which we shall call the " Water-freezing release " depends for its action on the well-known expansion of water on freezing The freezing takes place inside a metallic tube filled with water and the release will work only when the instrument reaches beyond a level at which the temperature is of the order of $-10°C$ —a temperature at which water is sure to freeze in spite of super-cooling and temperature lag Sounding balloons sent up with a view to have an unrestricted ascent mostly reach a much lower temperature, thus ensuring the freezing of the water and hence the working of the release

Fig. I (1) is a photograph of the " Water-freezing release " A is the water-filled tube, B is a lever capable of turning round the wire nail pivot C D is a wire-nail stuck through the wooden standard (K) which has a wooden off-set pin at E (same as E in Fig. I (2) which is more clearly in view) F is a spiral spring which, on being released, is intended to pull the wooden wedge that holds down the flat pen-lifting spring of the meteorograph. The tube A is shown in detail in Fig. II. It consists of two halves A_1 and A_2 each of which ends in a flange, (L_1 and L_2) The two halves are cemented together by a layer of shellac between the flanges. W (Fig. II) is a scroll of wire gauze soldered to the plug G_1 This scroll forms a core inside the tube A, leaving a space of about 1/32" all round. It helps the freezing of water and melting of ice. It also facilitates the two halves of the tube to be held together after the freezing cracks the shellac joint and separates the flanges.

It is clear from Fig. I that the spring F slips off the lever B when the two halves of the tube A separate. Sometime during the ascent of the balloon the water inside the tube A freezes and the resulting expansion cracks the shellac joint, but the two halves continue to be held together by the core of ice, against the pull exerted by the spring and the lever that tends to separate them. During the descent of the instrument, however, the ice melts at some stage and the two halves are pulled apart. The lever is thus made to turn round and the spring slips off.

From Fig III will be clear how the action described above is utilised to pull the wedge that holds down the pen-lifting spring. This wedge, as shown in Fig. IV at M, is inserted with its taper pointing upwards. The thread attached to the bottom of this wedge is tied to the stretched spiral spring of the release mechanism. (See Figs. III and IV). The release is attached to the instrument cage in the position as shown in Fig III with the help of the offset pin E, (Fig. I), which engages in a ferrule fixed to one longitudinal ring of the cage and is fixed in position by melted shellac. The position of the ferrule relative to the cage and the orientation of the release mechanism are so adjusted that the axis of the spiral spring is roughly in the same line as the string that joins it to the wedge of the meteorograph while in position inside the cage This adjustment ensures that, when the spring slips off the lever and its tension is transferred to the string, the whole—and not a mere component—of this tension is effective in pulling off the wedge Care is also taken not to leave any sag on the connecting string so that the maximum pull of the spring is made to act on the wedge.

It is obvious that the tension of the spring, the pressure of the pen-lifting spring on the wedge, the diameter of the tube and flange all require to be relatively adjusted in order to prevent failure in the action of the release-mechanism. It is also necessary to fill the tube A without leaving any air bubble inside This is done by unscrewing the plug G_2, filling the tube with water with the help of an air pump and finally screwing in the plug

Fig. V is the photograph of a trace from one of the meteorographs sent up with the pen release just described Points X and Y on the temperature and humidity traces respectively show where the pens have been lifted off the plate and have thereby prevented a blur It will be useful to compare this record with Fig VI wherein a trace obtained without the use of the pen-release is shown

The second type of release shown in Fig I (2) and Fig VII differs from the first type only in its mechanism for releasing the spring. Here, the tube A is replaced by the catch H which engages with the hook I at one end and an offset pin at the end of the lever B at the other end The lever is thus held inclined, engaging the stretched spring exactly as in the case of the water-freezing release The release of the spring is effected by disengaging the catch which is done by the pressure of a cork J blown off from the mouth of a small test tube R. This tube contains, just under the cork, a bolus L of cotton wool filled with sodium bicarbonate. A little solution of citric acid is contained at the bottom of the tube. The test tube is attached to one arm of a lever, to the other arm of which is attached a small sail S made of paper pasted over a light wire frame. This lever turns round an axis at right angles to the wooden upright K and in a plane parallel to that of the lever B. During ascent of the balloon the sail S hangs down and the test tube occupies a vertical position, as shown in Fig VII, but during descent the sail is caught in the upward draught and is therefore pressed upwards against the sides of the cage. The test tube thus takes up a position somewhat inclined downwards from the horizontal. In this position, the cork closing the mouth of the test tube points towards the catch H and is very near to it as shown in Fig I (2), also, the tilting of the tube brings the acid into contact with the bicarbonate inside the bolus of cotton wool. The pressure of carbon dioxide, generated in the chemical action that follows, blows out the cork which, in turn, disengages the catch. The rest of the action is identical with that of the water-freezing release.

The gas-pressure release, as we may call this, has been successfully used for restricted ascents in which the lowest temperature likely to be encountered by the instrument is higher than the working temperature of the water-freezing release. In temperate latitudes where the ground temperature is so low that the ice formed

in the tube of the first type of release has no chance of melting sufficiently, or at all, to release the two halves of the tube before the instrument strikes the ground, the gas pressure release can, by selecting a suitable acid, be used with advantage. The acid frozen during ascent will melt sometime during the descent and, except in exceptional circumstances, will come in contact with the cotton wool containing the carbonate ; the resulting chemical action will blow off the cork before the instrument reaches the ground. The cork should however be sufficiently tight to prevent it from being blown off or forced out during ascent due to reduction in the atmospheric pressure at high levels.

Fig. VIII is the photograph of a record from an instrument sent up with this type of release by means of a balloon arranged to deflate at a predetermined height. The pens in his case were taken off the plate almost immediately after the balloon began to descend after deflation.

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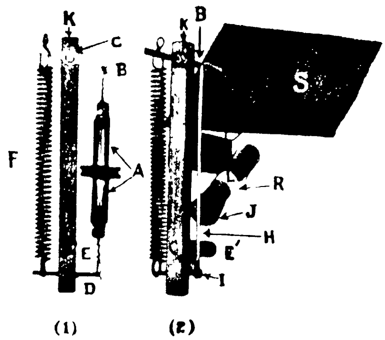
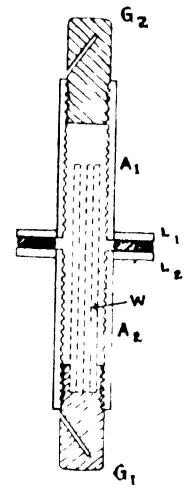


Fig I



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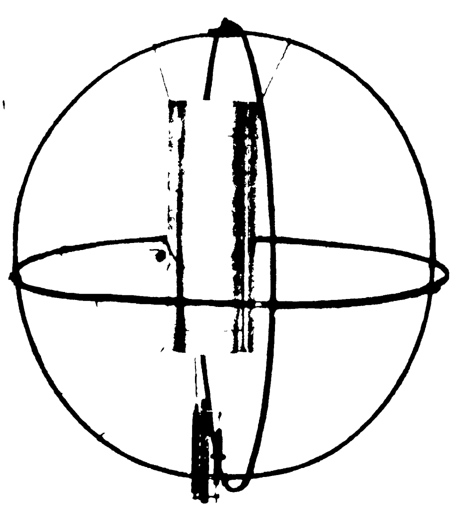

Fig III

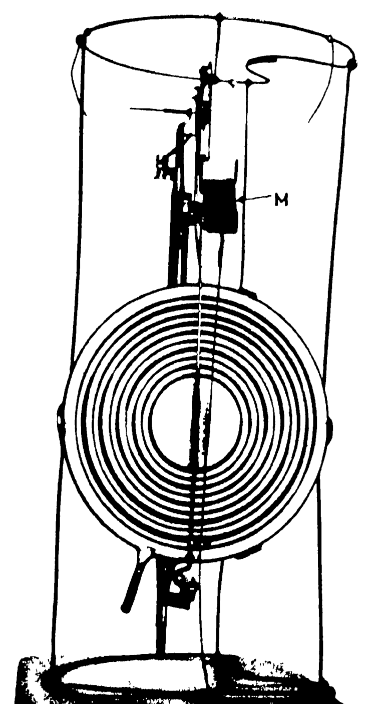

Fig IV

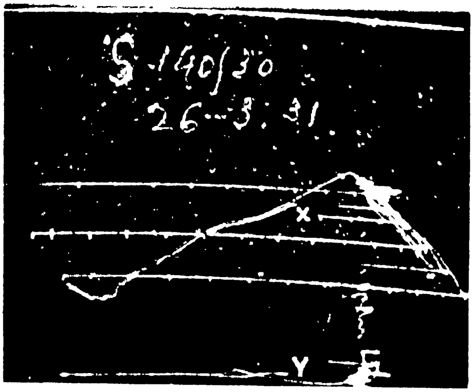

Fig. V

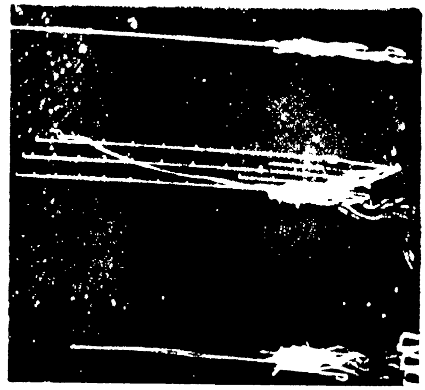

Fig VI

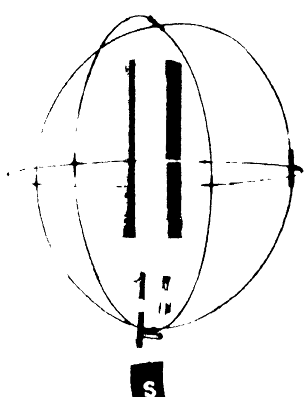

Fig VII

Fig VIII

G P Z O 1931

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SCIENTIFIC NOTES

Vol. IV, No. 35.

An Improved Method of Sounding the Lower Layers of the Atmosphere.

BY

G CHATTERJEE, M. Sc.

(*Received on 8th May 1931.*)

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AN IMPROVED METHOD OF SOUNDING THE LOWER LAYERS OF THE ATMOSPHERE.

BY

G. CHATTERJEE, M. SC.

(*Received on 8th May 1931.*)

In India, where a large percentage of sounding balloon meteorographs fail to be retrieved at all, the cheap Dines' meteorograph seems to be the only instrument suitable for Upper Air Sounding on a large scale. The temperature and pressure scales of the original Dines' meteorograph are however too small and thereby render it unsuitable for low ascents. The instrument has therefore been slightly modified at Agra so as to give pressure and temperature scales about twice as large as that of the original instrument.

When soundings of only the lower layers of the atmosphere are desired, it has to be arranged that either the meteorograph will be released from the balloon or the balloon itself will fall down after emptying itself of its hydrogen gas, when it has reached a predetermined height. The latter method is the more advantageous in so far as the balloon is retrieved and can be used again (this has been found possible with Vulpro tissue balloon used in India) and in that the balloon serves to attract the finder's attention better than the less conspicuous instrument with its bamboo cage. A contrivance by which a balloon is made to empty out its gas rapidly after a predetermined height is reached was developed some years ago by Mr. J. H. Field under whose direction the present author successfully used it to study the detailed thermal structure of the atmosphere in the first kilometre above ground over Agra. Later on, Mr. Field's method was successfully used by the author both at Agra and during an expedition in Bengal for detailed soundings up to a height of about 3 kilometers above ground. A description of Mr. Field's "Clown Balloon" as he called it will be given in another paper

The "Clown Balloon" as designed by Mr Field was not found suitable for carrying light instruments. It is not easy of manipulation in strong wind. It is also not quite hydrogen-tight and can therefore be used only for ascents of a few minutes' duration. For these reasons, another type of self-deflating balloon has been developed and found useful. A description of this type of balloon will precede that of the open-scale meteorograph of the Dines' type in the following pages.

The balloon used is one made of vultex tissue. It is without a neck but has a circular opening on its surface as shown at O in Figure I. This opening serves as the mouth through which the gas is emptied out. The mouth is normally kept closed by being pressed between two flat strips of wood W (See Figures III and IV). This is done after it is folded and stretched, as shown in Figure II, to remove the frills. The flat wooden strips are tied together, with the folded mouth of the balloon in between, in the manner shown in Figures III and IV. The cork wedges (C, Figure IV) keep the flat pieces of wood well pressed against each other and the balloon tissue, thus effectively and completely preventing escape of hydrogen gas. The tying of the mouth of the balloon between the wooden strips is done by a tape T which is intercepted as shown at A by a cotton thread treated with potassium chlorate. This thread passes through diametrically opposite holes in a tube U made of paper and treated with molten paraffin, which serves not only to stick the folds of the

paper but to make the tube acid-proof. The tube is made by wrapping paper round the same glass tube which is later on to be used as a container for the acid solution as described below. The balloon is filled with hydrogen through a second tubular opening (P, Figure VI) after the mouth is tied as described above.

A glass U-tube closed at one end and containing a saturated solution of chromic anhydride in sulphuric acid is utilised to burn the thread and open the mouth of the balloon. The column of sulphuric acid and the air-space above it at the closed end are so adjusted that, at the pressure and temperature corresponding to the height at which the balloon is desired to operate, the sulphuric acid reaches the open end of the U-tube, due to expansion of the air column. The length of the air column and its expansion are calculated with the help of the normal pressure and temperature for different heights as obtained from previous ascents. The acid-filled U-tube B is inserted in the paper tube (*vide* Figure V) such that the open end just touches the chlorated thread. When the balloon has reached a height roughly equal to the predetermined height, the acid comes in contact with the thread and burns it. Subsequent action of the balloon will be clear from Figure VI. The burning of the thread releases the wooden strips from the mouth of the balloon, which then opens out. At temperatures below 0°C there is always a tendency for the folded tissue to stick, even when the surfaces are dusted with french chalk. This is due to the freezing of the water vapour present in the gas. It is for this reason that the mouth has been provided on the spherical surface of the balloon instead of at the end of a neck, so that the tension of the inflated balloon assists the opening of the mouth after the wooden strips are released. As the instrument is suspended from loops attached to the pieces of wood and a thread D connects these loops to the top of the balloon (as shown in Figure VI) the weight of the instrument is transferred from the mouth to the opposite end as soon as the mouth opens out. The balloon thus inverts and the gas is emptied out of the open mouth , within a short time the balloon collapses and begins its descent with the instrument.

The chemical action which is responsible for burning the thread takes place only at temperatures higher than about −14°C The method of opening the mouth as described above has therefore its limitations Sulphuric acid of density 1·2 does not freeze and can react on alkali metals at temperatures much lower than the above. Experiments are in progress to utilize this chemical action to open the balloon mouth at lower temperatures.

Coming now to the open scale meteorograph, any one acquainted with the original Dines' instrument can clearly see, from Figure VII, the essential alterations that have been made to obtain a more open scale. The attachment of a second aneroid to increase the pressure scale needs no description but a short description of the temperature grid is perhaps necessary.

The grid is constructed more or less on the lines indicated by Fergusson* for an open scale meteorograph for use with rockets. A detailed view of the temperature grid is shown in Figure VIII. The frame C D E F is of invar. The loop L of the bridge piece allows the hair of the hygrograph to pass through without touching the grid or the frame of the instrument. The elements H, H′ are made out of hard drawn brass sheet ·010″ thick. This thickness has been found to give sufficient rigidity to the grid without introducing undesirable temperature lag. The spring hinges J and K are as usual pieces of watch spring. M is the hygrometer pen to which one end of the hygrometer hair is attached. The complete grid is attached to the frame of the instrument at two points A and B, Figure VII.

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* Vide Monthly Weather Review, Vol. 48, p. 321-322

Figure IX gives a comparative idea of the scales of the original Dines' instrument and the open scale instrument. The ranges covered by each set of calibration lines shown in the photograph are :—

Pressure, 559 mb.

Temperature, 31°C.

The photograph shows the original magnified 3 times.

Figure X is the record obtained by an instrument fitted with the double temperature grid and a single aneroid. For unrestricted ascents such instruments are being used in India in place of the usual Dines' instruments, as the records obtained from the former can be measured more accurately. The temperature range covered by the calibration in the record mentioned above is 80°C. The photographic magnification of the record is 4.

Figure XI is a record obtained by the use of the modified instrument with two aneroids and a double temperature grid. The trace extends to about 4·5 kms. and the photograph shows the trace magnified 4 times.

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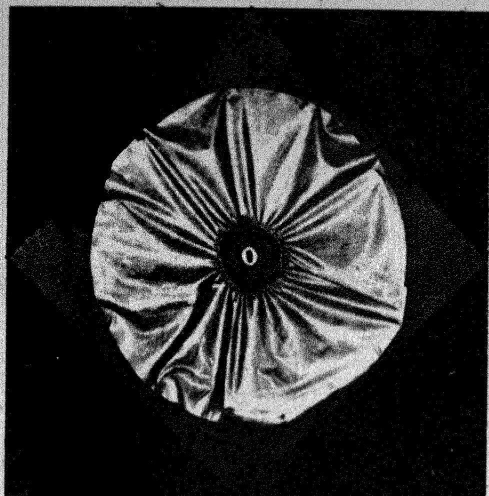

FIG I

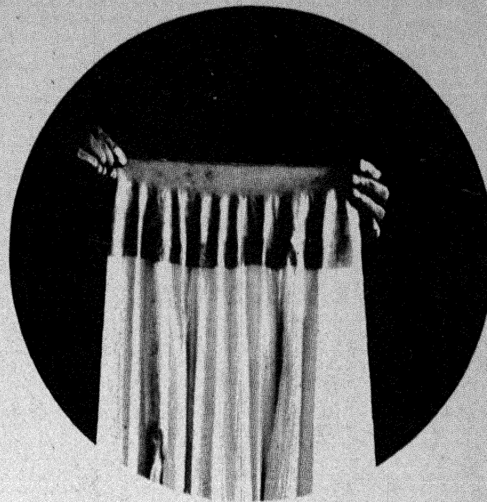

FIG II

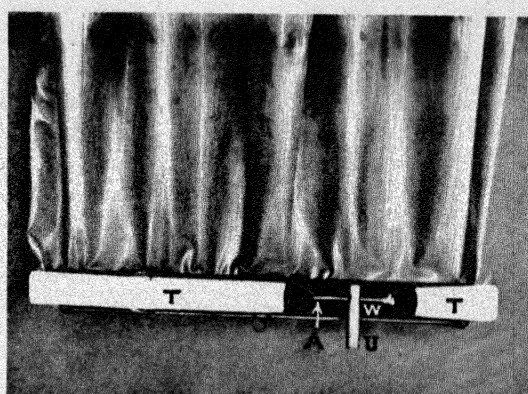

FIG III

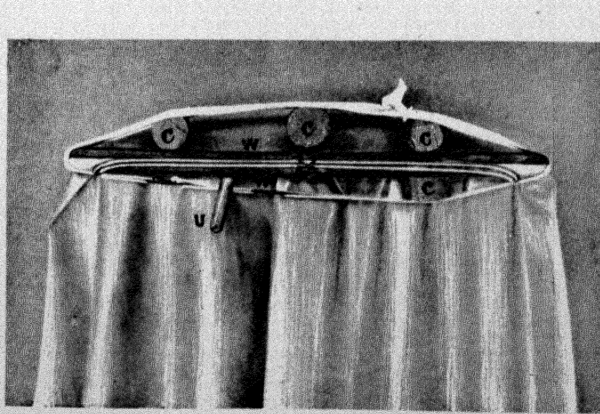

FIG IV

G.P.Z.O. 1931.

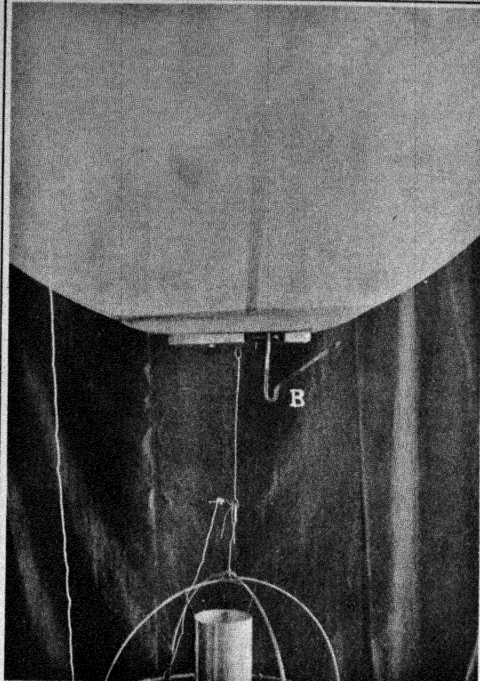

FIG.V.

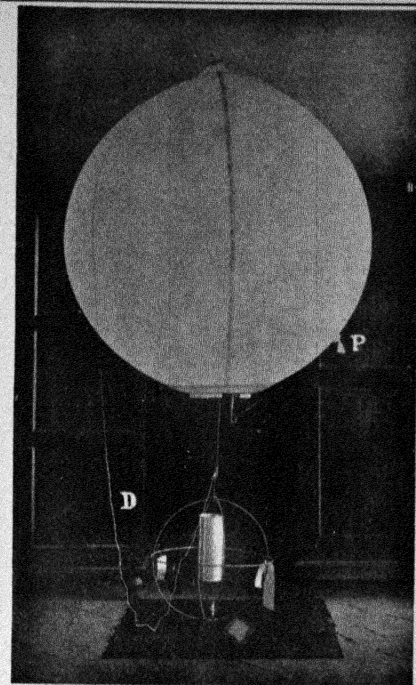

FIG.VI.

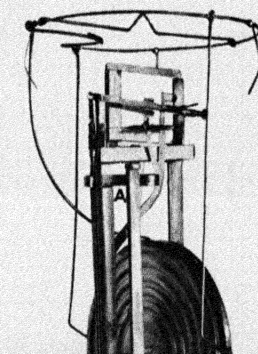

FIG.VII.

G. P. Z. O. POONA, 1931.

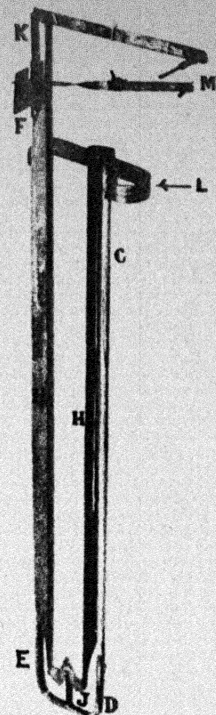

Fig. VIII

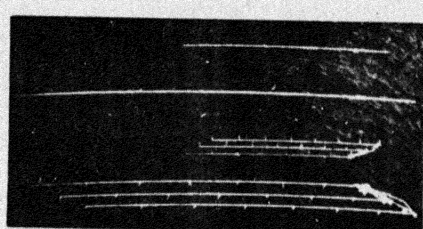

Fig. IX

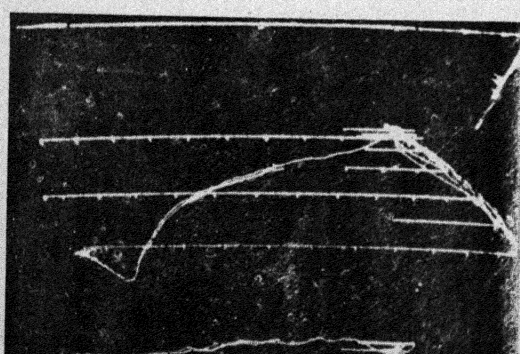

Fig. X

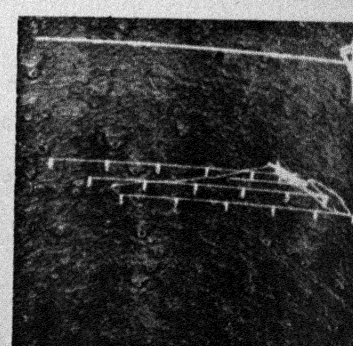

Fig. XI

G.P.Z.O.1931.

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The Lunar Atmospheric Tide at Kodaikanal and Periyakulam

BY

S. K. PRAMANIK, M.Sc., Ph.D., D.I.C., S. C. CHATTERJEE, B.Sc.

and

P. P. JOSHI, B.Sc.

(Received on 5th March 1931)

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THE LUNAR ATMOSPHERIC TIDE AT KODAIKANAL AND PERIYAKULAM (1902—1908)

BY

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CONTENTS.

1. This paper is a continuation of a similar paper by one of the authors,[1] dealing with the atmospheric tide at Bombay. The determination of the atmospheric tide at Greenwich,[2] Batavia and Hongkong,[3] Aberdeen,[4] Mauritius and Tiflis,[5] and Madras, Helwan and Mexico[6] has been given by Chapman and his collaborators and at Potsdam and Hamburg[7] by Bartels. The determination for two more stations, Kodaikanal and Periyakulam, have been given in this paper.

2. Kodaikanal is situated on the Palni hills in South India, its approximate geographical co-ordinates being—

Latitude	10° 14′ North
Longitude ..	77° 28′ East

The height of the barometer cistern above sea level was 7,688 ft.

Periyakulam is situated at a distance of about 5 miles from the foot of the Palni Hills, its approximate geographical co-ordinates being—

Latitude	10° 09′ North
Longitude .	77° 33′ East

The height of the barometer cistern above sea level was about 911 ft.

The difference in the height of the two barometers was 6,711 ft., and the distance between the two stations was only about 8 miles. Except Mexico, which is about 7,480 ft. high, all the stations for which the lunar atmospheric tide has been determined are low level stations, most of them being situated on or near the sea coast. The pressure data for Kodaikanal and Periyakulam are suitable for the determination of the dependence upon and variation with height of the lunar

1. S. K. Pramanik, Mem. Ind. Met. Dept. Vol. XXV, Part 8.
2. S. Chapman, Q. J. R. Meteor. Soc. 44, 1918, p. 277.
3. S. Chapman, *ibid.*, 45, 1919, p. 113.
4. S. Chapman and E. Falshaw, *ibid.*, 48, 1922, p. 246.
5. S. Chapman, *ibid.*, 50, 1924, p. 99.
6. S. Chapman, and M. Hardman, Memoir R. Meteor. Soc. II, 19, 1928, p. 153.
7. J. Bartels, Veroff. d. Preuss. Met. Inst., Abh. Bd. VIII Nr. 9, 1927.

atmospheric tide, which has not been investigated so far. One of the main objects of the present analysis was to get an idea of this dependence upon and variation with height.

3. The hourly values of barometric pressure at Kodaikanal and Periyakulam used in this determination were obtained from the tabulation of similar Richard barographs which were daily compared a number of times with a standard barometer. The period covered by the date for both the stations was the seven years, 1902-1908. The hourly pressure data for Kodaikanal and Periyakulam are neither so accurate nor so reliable as for Bombay and the number of years for which data have been analysed in this paper is much less

4. The method followed in the reductions was similar to that adopted by Pramanik in the determination of the lunar tide at Bombay which was based on the method used by Chapman. Twenty-six columns were used to allow for the non-cyclic variation. The mean monthly solar diurnal variations were removed from the data of the corresponding months before tabulation for computation. Days of range greater than or equal to ·01″ after the removal of the solar diurnal variations, and also days for which some hourly readings were missing, were neglected The number of days thus neglected was 3 for Kodaikanal and 92 for Periyakulam The analysis in this case is less detailed than for Bombay, as results for the 9 declination and the 8 distance groups were not worked out The diurnal inequalities for groups of days centred at apogee and perigee were, however, formed and the harmonic coefficients calculated.

5. Small phase corrections were necessary for Kodaikanal and Periyakulam as the times of lunar transit at Greenwich, directly obtainable from the Nautical Almanac, were used in the computations instead of the times of lunar transit at these places. The corrections on this account for Kodaikanal and Periyakulam were —5·3° and —5·4° for the second Fourier component

A further correction was necessary as the calculations did not refer to full hours of local mean times but to I S. T or almost 20 minutes earlier On this account the corrections for Kodaikanal and Periyakulam were —9·7° and —9·5°

Thus the total phase corrections were as follows :—

Kodaikanal	—15·0°
Periyakulam	—14·9°

The unit employed for pressure is 1 microbar

The annual mean atmospheric tide.

6. The period of seven years for both the stations was divided into 2 groups of 4 and 3 years, and each of these groups was analysed separately. The values of the second Fourier coefficients are given below :—

Table I. Annual Mean Lunar Atmospheric Tide.

	Period.	No of days.	C_2	θ_2	Period.	C_2	θ_2
Kodaikanal	1902-05	1,409	57	70	1902-08	52	68
	1906-08	1,058	47	65			
Periyakulam	1902-05	1,362	54	67	1902-08	52	62
	1906-08	1,016	49	58			

Both for Kodaikanal and Periyakulam, the amplitude and phase are greater for the first than for the second period. The mean amplitude for the two stations are equal, though the mean phase is about 6° greater for Kodaikanal. Thus there appears no appreciable change in amplitude with height, but the phase is greater by about 6° at the higher station.

The seasonal mean atmospheric tide.

7. The results of summer, winter and equinox, including respectively the months May to August, February to March and March, April, September and October, are given below for the two periods of 4 and 3 years.

Table II. Lunar Atmospheric Tide in Summer.

	Period	No. of days.	C_2.	θ_2.	Period.	C_2.	θ_2
Kodaikanal	1902-05	474	47	82	1902-08	49	80
	1906-08	356	51	78			
Periyakulam ..	1902-05	460	42	68	1902-08	47	65
	1906-08	345	52	63			

The amplitude is greater in the second period while the phase is greater in the first for both the stations. The mean amplitudes for the two places are almost equal while the phase is greater for Kodaikanal.

Table III. Lunar Atmospheric Tide in Equinox.

	Period.	No. of days.	C_2.	θ_2.	Period.	C_2.	θ_2.
Kodaikanal	1902-05	470	71	91	1902-08	61	82
	1906-08	353	51	74			
Periyakulam	1902-05	446	72	78	1902-08	63	68
	1906-08	330	53	58			

Both for Kodaikanal and Periyakulam the amplitude and the phase are greater for the first period than for the second. The mean amplitudes for the two stations are nearly equal while the phase for Periyakulam is less.

Table IV. Lunar Atmospheric Tide in Winter.

	Period.	No. of days.	C_2.	θ_2.	Period.	C_2.	θ_2.
Kodaikanal ..	1902-05	465	33	42	1902-08	38	42
	1906-08	349	43	41			
Periyakulam ..	1902-05	456	35	44	1902-08	36	39
	1906-08	341	38	35			

For both the stations the phase is somewhat greater for the first period than for the second while the amplitude is greater for the second period. Here also the mean amplitudes for the two stations are about equal while there is a tendency for the phase to be slightly greater for Kodaikanal

8. For all the seasons both for Kodaikanal and Periyakulam θ_2 decreases and the variation in C_2 is similar from the first to the second period. The variation in C_2 and θ_2 from one season to another at the two stations are similar, the maxima occurring in equinox and the minima in winter. It appears from a comparison with other stations[1] that the variation in θ_2 at Kodaikanal and Periyakulam is similar to that at most stations for which the atmospheric tide has been calculated, while the variation in C_2 is similar to that at Samoa and Hamburg only.

9. The mean amplitudes at the two stations are nearly equal, while there is a tendency, more marked in the summer and equinox than in the winter, for the phase at the higher station to be greater.

The variation in atmospheric tide with lunar distance.

10. The results of the groups of days centred at apogee and perigee are given below .

Table V. Lunar Atmospheric Tide at Apogee and Perigee.

	Period.	No. of days.	C_2.	θ_2	Period.	C_2.	θ_2.
Apogee—							
Kodaikanal ..	1902-05	212	29	82	1902-08	37	85
	1906-08	160	44	87			
Periyakulam ..	1902-05	212	35	82	1902-08	34	77
	1906-08	160	33	72			
Perigee—							
Kodaikanal ..	1902-05	212	64	66	1902-08	66	60
	1906-08	160	68	53			
Periyakulam ..	1902-05	208	56	57	1902-08	64	55
	1906-08	160	73	53			

At both the stations the amplitude increases from apogee to perigee by an amount much larger than that expected from the equilibrium theory. The phase decreases

[1]. S. K. Pramanik, Mem. Ind. Met. Dept., Vol. XXV, Part 8, Table VI.

by about 25° at both the stations from apogee to perigee. This decrease in phase is similar to, though greater in amount than, the corresponding decrease at Bombay. Both at apogee and perigee the mean amplitudes at Kodaikanal and Periyakulam are nearly equal, while the mean phase is greater at Kodaikanal.

Conclusion.

11. The main conclusions are :—

(*i*) The amplitudes of the semidiurnal component of the lunar atmoshperic tide (annual mean, summer mean, equinox mean and winter mean, and at apogee and perigee) at Kodaikanal and Periyakulam are nearly equal. This would definitely indicate that the amplitude of the second component of the lunar tide does not vary with height, (up to about 9,000 ft.).

(*ii*) The phase of the second component is somewhat greater, (about 5° in the mean), at Kodaikanal than at Periyakulam.

(*iii*) The second component increases in amplitude from apogee to perigee, that at the latter being almost double of that at the former. The phase, as for some other places, decreases from apogee to perigee

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